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Field Note: Learning from Early Application of a Transition Forest Climate Adaptation Planting Strategy Incorporating Assisted Migration in Southern New England

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Abstract

This field note presents an early example of a forest climate adaptation tree planting project incorporating assisted migration in southern New England which is valuable in providing lessons that can inform future work in this region and elsewhere. This effort is notable for moving forward through the implementation and monitoring stages during a period when many similar projects encountered barriers. The project is located on watershed protection forestland owned by the Providence Water Supply Board, a public utility in Rhode Island. Using a suite of tools developed through the Climate Change Response Framework, watershed forest managers carried out a "transition" strategy climate adaptation planting in 2015, seeking to improve regeneration in an area of forest near the state's main drinking water reservoir. Seedlings of both native and assisted migration tree species projected to be adapted to future climate conditions were planted in adjacent areas that had experienced oak regeneration failure. Half of the seedlings of each species were planted within a deer exclosure fence and half were planted in an unfenced area. Annual monitoring has allowed for comparison of survival and growth of a subset of planted trees at these two sites for 10 growing seasons. Deer herbivory is believed to be the most significant factor contributing to differences in tree survival rates between the fenced and unfenced areas. Both native and non-native species have been able to survive when protected from deer browse, while differences are inconclusive after nearly a decade. This informal experimental planting provides a case study illustrating some of the opportunities and challenges associated with implementing assisted migration in a non-research, operational-scale setting.

Keywords adaptation planting · assisted migration · climate forestry · forest adaptation · transition adaptation strategy · watershed forestry

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Introduction: A Project From the First Generation of Forest Adaptation Planning

As forests, along with ecosystems of all types, encounter growing impacts from climate change, environmental managers are increasingly reevaluating and updating decades-old goals, objectives, and tactics to respond to these pressures. In response to this enormous challenge, the USDA Forest Service (Forest Service) launched a community effort called the Climate Change Response Framework (CCRF) in 2008 to address the challenges that land managers face when considering how to integrate climate change into planning and management activities (CCRF 2024). In the Midwest and Northeast, a Forest Service-led partnership called the Northern Institute of Applied Climate Science (NIACS) has played an important role in operationalizing forest adaptation planning. One of the key components of the CCRF has been fostering the development of on-the-ground demonstrations, with the earliest demonstrations being developed about 10 years ago (Swanston et al. 2016; Janowiak et al. 2014).

At the same time, researchers began articulating adaptive strategies for managing forests in the context of an uncertain but changing future climate. Millar et al. (2007) categorized adaptive strategies into three options: **resistance** (forestall impacts and protect resources), **resilience** (improve capacity to rebound from disturbance), and **response** (facilitate transition to new conditions) options (Millar et al. 2007). More recent adaptation efforts, including the Adaptive Silviculture for Climate Change (ASCC) Network of silvicultural experiments described by Nagel et al. (2017), have reworded the response option as **transition** to characterize its focus on intentionally directing the development of ecosystems toward novel and transformed conditions. As the climate adaptation field evolves, other scientists have presented an array of adaptation frameworks to reflect a spectrum of choices, all of which include change-oriented options (e.g. St. Laurent et al. 2021; Schuurman et al. 2022).

The transition adaptation option seeks to actively anticipate and accommodate ecosystem change, often through favoring or introducing species that are expected to be adapted to projected future conditions (Swanston et al. 2016). These strategies have increasing relevance as climate and environmental changes are driving ecological transformation to new conditions (Jackson 2021). Because they are intended to facilitate change to future-adapted and often novel conditions, transition strategies may include assisted migration as a tool to alter species composition (Millar et al. 2007, Twardek et al 2023).

Assisted migration is a general term for humans intentionally moving genotypes, populations, or species to locations or areas outside of their current ranges to maintain biological diversity or ecosystem function in response to climate change (Richardson et al. 2009; Schwartz et al. 2012; Bower et al. 2024). In forestry, the practice focuses on the movement of populations of commercially or ecologically important forest tree species as a way to maintain forest productivity and health in the face of climate change (Bower et al. 2024). Assisted migration actions can be divided into three broad categories. Assisted *population* migration moves trees or seeds of species from existing populations to new locations or zones within the species range. Assisted *range expansion* moves trees from populations within the species range to locations that are just beyond the current species range, mimicking the ability of a species to disperse to new habitat. Finally, assisted *species* migration moves trees from populations to new locations beyond the range of natural plant dispersal, overcoming any natural migration boundary. At present, the distinction between range expansion and species migration is somewhat ambiguous both due to a lack of standardized terminology and challenges in estimating natural migration potential of a given species across a fragmented landscape. The first category is generally considered the most conservative and the third the most bold or risky (Schwartz et al. 2012; Williams and Dumroese 2013; Palik et al. 2022; Bower et al. 2024).

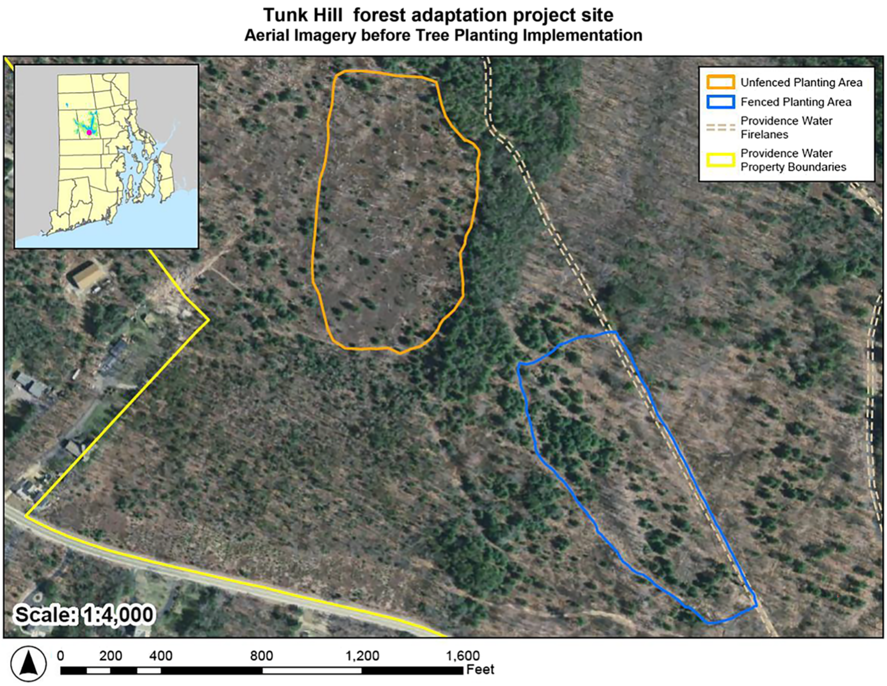
Despite perceived risks, the intent of assisted migration is to maintain future ecosystem health and it is a tactic that forest managers have used for decades (Schwartz et al. 2012). Use of assisted migration to combat climate change has gained attention since the mid-2000s, but a lack of operating procedures, climate uncertainty, and concern about risk have hampered implementation (Williams and Dumroese 2013). Despite recent examples of operational-scale projects, routine use of assisted migration in forest conservation may lag behind the need for its use to reduce risks to ecosystem function from climate change impacts (Palik et al. 2022; Clark et al. 2023).

In this paper, we present some lessons from implementing a transition-focused adaptation planning incorporating assisted migration from the southern New England state of Rhode Island. While not a research study, this early-adoption project highlights the realities of implementing adaptation at an operational scale (details and photos available at www.forestadaptation.org/providence). In particular, few managers to date have employed such tactics in the context of global change, often focusing on less risky approaches in line with historic practices (Himes et al. 2023; Schattman et al. 2024). Now nearly a decade old, this project received a significant external interest from regional professionals and media sources including *The Forestry Source* (Watts 2018), *The New York Times* (Velasquez-Manoff 2019), and USDA Northeast Climate Hub website (USDA Northeast Climate Hub 2016). More than for its results, the project is informative as an example of a "transition planting" that moved forward through the implementation and monitoring stages during a period when many similar projects never passed the conceptual stage or encountered barriers to actualization.

Landowner Context and Pre-Treatment Site Conditions

The Providence Water Supply Board is a public utility that supplies drinking water to about 600,000 people in Rhode Island. The utility's source water supply originates in a 93-square mile watershed located in an inland area of Rhode Island west of the Providence metropolitan area. The main Scituate Reservoir (Latitude 41°46′30″ N; Longitude 71°36′18″ W) and five smaller tributary reservoirs are surrounded by 13,000 acres of mostly forested public land dominated by oak-hickory *(Quercus-Carya)* and pine-oak *(Pinus-Quercus)* forest types. These lands serve as "green infrastructure" that performs the first step in the water treatment process: filtering surface runoff. This prevents the city-owned public utility from having to invest in additional expensive treatment facilities. Providence Water has actively managed the land since the creation of the reservoir system in the 1920s with an overarching goal of producing high-quality drinking water. The desired forest condition is a mosaic of stands with trees of different species and ages, based on the premise that forest diversity may help promote resiliency to disturbances that could negatively impact water quality (Barten et al. 1998; Providence Water Supply Board 2011).

The climate adaptation planting site is (Map 1) situated on the interior of a wide peninsula of the Scituate Reservoir, about a half mile from the nearest shoreline. Near the broad crest of Tunk Hill, the project area is an unproductive upland oak growing site with rocky and well-drained fine sandy loam soils of the co-occurring Canton and Charlton series, which have estimated 50-year site indices of 58 and 65 for Eastern white pine *(Pinus strobus)* and 52 and 65 for Northern red oak *(Quercus rubra)*, respectively (USDA Natural Resources Conservation Service 2024). Following widespread mortality caused by the orange-striped oakworm *(Anisota senatoria)* and other pests, a salvage timber harvest targeting dead and dying trees was conducted over 2006–07. Many of the remaining canopy trees died in part due to drought and repeated defoliation. Some young white pine had become established,



Map 1 Tunk Hill Forest adaptation project site: Aerial imagery before tree planting implementation (Providence Water Supply Board 2025)

but otherwise the site had largely become an example of regeneration failure (Fig. 1). A low-intensity 2010 inventory for property-wide management planning recorded an overall basal area of 35 square feet per acre (8 square meters per hectare) in this stand with even sparser areas (Providence Water Supply Board 2011).

Around the same time, a nearby stand of planted red pine became infested by the red pine scale *(Matsucoccus matsumurae)* and red pine adelgid *(Pineus boerneri)*. The trees were cut before they died to try to establish regeneration, but a combination of the high white-tailed deer *(Odocoileus virginianus)* population's browsing of desired seedlings and invasive plant colonization largely inhibited native tree and plant establishment beyond a population of white pine similar to the previous site, along with scattered oaks. The same 2010 inventory recorded a basal area of 18 square feet per acre (4 square meters per hectare) in this stand (Providence Water Supply Board 2011). With grant funding, a 6-acre deer exclosure fence was constructed in 2011 as a demonstration. Invasive plants within the exclosure were treated using mechanical and chemical methods.

Although the oak salvage and red pine scale-infested sites, located within a few hundred feet of each other, had different management histories, they overlie similar soils and in 2015 they were both in a comparable early successional condition with open areas interspersed with young trees. In addition to drought, deer herbivory, and insect pests, young trees also had to compete with a dense shrub layer of huckleberry *(Gaylusaccia* spp.*)* and other species making it more difficult for them to become established.

Fig. 1 Conditions at the unfenced project site during the fall before tree planting, 2014, Scituate, Rhode Island. Photo credit: Christopher Riely

Project Origins

Providence Water land managers recognized the forest health and regeneration challenges at the site. This section of the property was the first to be included in a new deer management program (including both controlled hunting and vegetation monitoring) begun in 2010 (Providence Water Supply Board 2011 and 2024). Conditions were also described in the Scituate Reservoir Watershed Property's 2011–20 Forest Stewardship Plan: "Coniferous seedlings are subject to deer herbivory and hardwood seedlings stand little chance of developing. If the controlled hunt is successful in reducing the deer impact, an aggressive planting program should be considered in this area of the management unit (Providence Water Supply Board 2011)."

While implementing the plan, Providence Water land managers participated in a 2014 "Adaptation Planning and Practices" workshop hosted by NIACS that focused on forest ecosystems in New England. Offered in different formats and locations, this hands-on training is intended to help natural resources managers incorporate climate change considerations into their own real-world forest management projects using the five-step Adaptation Workbook (Schmitt et al. 2021). Among other outputs, the first steps led to identification of the Tunk Hill site as a specific location vulnerable to climate impacts and unlikely to improve without significant intervention. In fact, the degraded forest conditions led foresters to believe that there was little to lose in experimenting with a transition approach and organizational managers supported their decision.

Methods

From a forest management perspective, the project was conceived as an aggressive adaptation response with a goal of improving regeneration conditions. It was also designed as an informal experimental seedling planting trial to test the survival and growth of both native conifers and hardwoods and non-native species currently found in the mid-Atlantic region that may see future northward range expansion. The presence of the pre-existing deer exclosure fence provided an additional opportunity to assess deer browse impacts given current challenges to regeneration (McWilliams et al. 2018) that may increase as a result of climate change (Janowiak et al. 2018).

NIACS team members worked with Providence Water land managers to help guide development of the planting. Providence Water foresters used the Climate Change Tree Atlas (Peters et al. 2020) to identify and select a mix of both native species and non-local species not found further north than New Jersey that are projected to become capable of growing in Rhode Island in the future. By planting several species north of their current range limits, the project incorporated assisted migration into its experimental strategy.

Species selection was also influenced by nursery availability. A nursery in Maryland was selected for its ability to provide a desired range of species. The planting ultimately included 1,700 bare-root seedlings of 11 species, which were divided evenly between the two sites (Table 1).

Table 1 Tree species planted. All seedlings planted were 1-year-old (1–0) bare-root stock from a Maryland nursery

Tree species	Seed Source	Presence in region's rural forests	Assisted migration strategy	Percent survival (fenced subset)*
Conifers (250 each)				
Eastern redcedar *(Juniperus virginiana)*	Maryland	native	N/A	10%
loblolly pine *(Pinus taeda)*	Maryland	not currently present	assisted range expansion	60% (all pine species together)
pitch pine *(Pinus rigida)*	Maryland	native	N/A	
shortleaf pine *(Pinus echinata)*	Missouri	not currently present	assisted range expansion	
Hardwoods (100 each)				
black locust *(Robinia pseudoacacia)*	unknown	non-native with limited distribution	assisted population expansion	33%
black oak *(Quercus velutina)*	unknown	native	N/A	64%
persimmon *(Diospyros virginiana)*	unknown	not currently present	assisted range expansion	0%
pin oak *(Quercus palustris)*	Maryland	native	N/A	data not available
sassafras *(Sassafras albidum)*	Missouri	native	N/A	0%
sweetgum *(Liquidambar styraciflua)*	Maryland	not currently present	assisted range expansion	60%
white oak *(Quercus alba)*	Maryland, Pennsylvania	native	N/A	30%

*Percent survival of tagged subset of seedlings planted within deer exclosure fence and tracked over 10 growing seasons

Providence Water typically conducts a modest amount of tree planting on its forestlands each spring, and the May 5–7, 2015, planting operations only differed by tree species selected. Members of Providence Water's watershed maintenance crew, who had limited tree planting experience, hand-planted the seedlings with spades (Fig. 2). Foresters instructed the crew to plant seedlings at suitable microsites (rather than in rows) within the two paired planting areas. They asked crew members to broadly distribute seedlings of each species, but did not provide specific spacing guidelines. At each site, individual crew members planted different combinations of trees following their understanding of the planting instructions and a demonstration. Due to dry weather and soil conditions, as many seedlings as possible were watered the day after planting using backpack water sprayers.

Monitoring and Results

After planting, 10 individuals of each species at each site (a total of 20 of each species) were tagged to allow for comparison among species and between fenced and unfenced seedlings. Initial challenges in distinguishing among the seedlings of the three similar pine species led to the pines being collectively monitored as a genus.

Fig. 2 Members of Providence Water's watershed field crew planting seedlings of both native and assisted migration tree species, 2015, Scituate, Rhode Island. Photo credit: Christopher Riely

Land managers have now conducted annual monitoring of this subset of planted trees for 10 growing seasons. Monitoring information collected includes planting stock survival (live/dead), height measurement to determine annual growth, and damage from factors including deer browse. At both the fenced and unfenced planting sites, tagged seedlings were distributed over several acres with rapidly changing young forest vegetation, so it was difficult to find all of them, especially seedlings that had died. Hence there is likely error associated with survival estimates.

A spring drought during the weeks following planting led to significant mortality among the seedlings, especially the conifers. The hardwoods appeared to have higher survival and growth rates during the first couple of years, perhaps because they were more drought tolerant or had more stored reserves (Fig. 3). More recently, some of the pines (especially those planted in favorable microsites) have realized height growth at a rate exceeding the hardwood species.

Between drought and deer browse, hardly any of the unfenced seedlings remained alive after five years and none appeared to be remaining by 2019 (Fig. 4). Bushy white pines that established naturally before the planting have grown to pole size and started to fill in the unfenced area. With starkly different survival rates between the fenced and unfenced areas, deer browse appears to be the most significant factor influencing survival among all species of both native and non-native seedlings. Monitoring has only been conducted within the deer exclosure since 2020. Deer browse has also notably influenced height growth of the remaining live trees. While the average height of surviving trees in the unfenced area flatlined from the beginning, the height of their counterparts within the exclosure rose steadily to an average of nearly 90 inches (229 cm) by 2024 (Fig. 5).

As of 2024, 26 trees from the original subset of 90 within the deer exclosure continue to be measured. Nine of the original 11 species are still present, with oaks, pines, and sweetgum (*Liquidambar styraciflua*) most abundant and only persimmon (*Diospyros virginiana*) and sassafras *(Sassafras albidum)* no longer confirmed to be persisting. Surviving seedlings within the exclosure have experienced widely varying levels of growth success. Loblolly pine *(Pinus taeda)*, black locust (*Robinia pseudoacacia)*, and sweetgum have seen the most dramatic height growth, with the

Fig. 3 A black oak seedling growing amidst competing shrubs, one year after planting, 2016, Scituate, Rhode Island. Photo credit: by Karrah Kwasnik

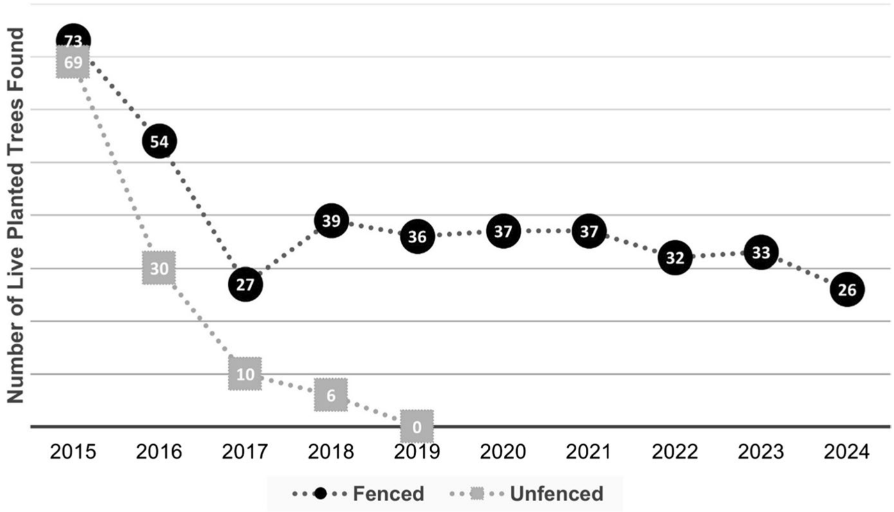


Fig. 4 Number of live planted trees found within monitoring subset (fenced vs. unfenced). The sample size of 180 trees (90 fenced and 90 unfenced) selected for monitoring represents a subset of the 1,700 total trees divided evenly between the two planting sites. 10 individuals of each species at each site (a total of 20 of each species) were tagged and monitored annually as vegetation conditions changed

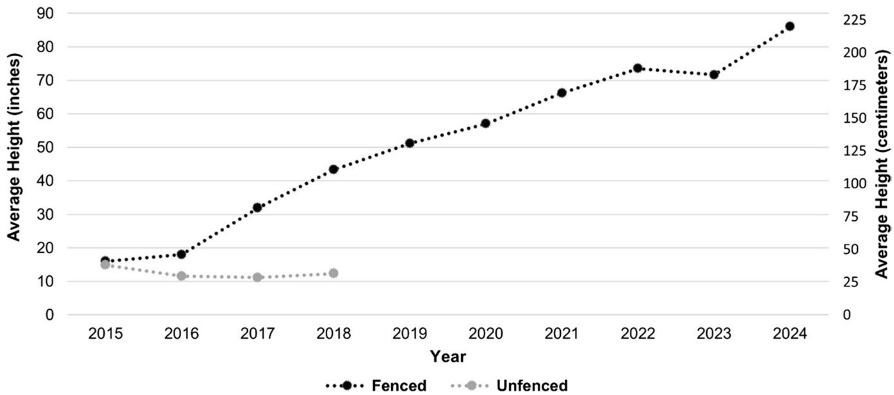


Fig. 5 Average height of live planted trees found within monitoring subset (fenced vs. unfenced). The sample size of 180 trees (90 fenced and 90 unfenced) selected for monitoring represents a subset of the 1,700 total trees divided evenly between the two planting sites. An exclosure fence was used as a control to assess the effects of deer browse on planted seedlings. Along with starkly different survival rates, the difference in height growth between the trees planted in the fenced and unfenced areas stands out. These average height measurements include seedlings with dead tops that have resprouted

largest individuals now in the 12–20 foot (4–6 m) height range (Fig. 6). The differences between native and assisted migration species are inconclusive due to the small total number of trees and variations in microsite quality. Some of the novel

Fig. 6 Planted loblolly pines growing within deer exclosure fence nine years after planting, 2023, Scituate, Rhode Island. Photo credit: Christopher Riely

assisted migration species do appear to be capable of persisting through current Rhode Island winter conditions.

Lessons Learned

Providence Water land managers became motivated to pursue this project as they learned to recognize the watershed forest property's climate vulnerabilities. The Tunk Hill project area had crossed an undesirable forest health threshold from pest, deer, and climate impacts, which prompted managers to consider the use of more experimental or outside-the-box transition strategies (McGann et al. 2023). The fundamental goal of this adaptation project was to successfully establish future-adapted tree species following regeneration failure. After nearly ten years, the results suggest that a range of assisted migration species matched to the site can persist, and sometimes potentially thrive, alongside native species in current climate conditions. Including the deer fence as a control for browse underscored the importance of protecting planted trees. Within the exclosure, outcomes have highlighted the influence of planting microsite quality, competing vegetation, and growth rates. The most successful trees are fast-growing species that have benefitted from favorable sites and lower competition, while slower–growing seedlings planted close to the pre-existing natural regeneration have been overtopped by white pines. The varied species and structural composition will likely present future managers with different options. At the unfenced site, regeneration continues to be sparse with the exception of the scattered bushy white pines.

This project is relatively novel in its focus on future-adapted regeneration, including assisted migration, which is increasingly being explored as an active adaptation strategy (Palik et al. 2022; Clark et al. 2024). The species selected for planting represented a curated mix of native species and two forms of assisted migration species (assisted population migration and assisted range expansion) intended to diversify forest composition and allow multiple pathways for ecosystem transformation (Table 1). Several non-native hardwood species have successfully established, and although it was not feasible to evaluate the pine species separately, the overall success of planted pines represents a notable change in composition compared to historic local plantings of red pine and native white pine. Loblolly pine and sweetgum are pushing into the canopy in close proximity to native pitch pine *(Pinus rigida)* and black oak *(Quercus velutina)*. After ten years, site observations suggest that with limitations on deer browse, adaptation plantings may be able to significantly alter forest composition and foster novel mixtures of native and assisted migration species. At the same time, this project highlights several operational challenges to implementing assisted migration in non-research projects, including significant advance planning time, limited availability of appropriate planting stock, lack of experienced tree planters in some regions, and difficulties in implementing efficient monitoring protocols (Clark et al. 2024).

The adaptation planting included informal experimental elements from the beginning but was never structured as a formal research project. More robust planning and structure from the beginning could have enhanced the value of its findings. The partnership might have benefitted from including researchers from a regional land grant university or environmental nonprofit, while adding additional complexity could have delayed or potentially even prevented implementation. Formal research is now being conducted to assess the efficacy of the transition strategy and different forms of assisted migration, among other approaches, in different ecosystems including southern New England oak-hickory forests (Palik et al. 2022, Adaptive Silviculture for Climate Change Network 2024). Experimental frameworks like the Adaptive Silviculture for Climate Change (ASCC) Network and Desired Regeneration through Assisted Migration (DReAM) efforts will provide valuable scientific and operational insights as results become available (Nagel et al. 2017; Royo, et al. 2023).

Although the field of climate adaptation is advancing, significant barriers remain for foresters implementing transitional strategies (McGann et al. 2023). Notably, the land managers involved in this project viewed the adaptation planning process as a professional development opportunity, rather than another hurdle or obstacle to achieving forest management goals. Training and ongoing support from NIACS adaptation specialists was important for helping facilitate development and implementation of this project, which would not have been conceived without the initial spark from an Adaptation Planning and Practices workshop. Support from Providence Water managers at different organizational levels was critical to seeing the project implemented on the ground and sharing it with external audiences. Climate change is now identified as a source water threat in the utility's Water Quality Protection Plan and the utility has developed a climate adaptation plan for the watershed. While numerous studies identify barriers to adaptation, further exploration of "early implementer" projects like the Tunk Hill site could provide valuable information about the factors that enable projects to overcome barriers.

The Tunk Hill adaptation project has advanced the discussion on climate change adaptation within the forestry community, in the media, and among interested members of the public. Among foresters, it has helped address the gap between research science and practice by showing that transition can be bold, innovative, and experimental rather than simply risky, especially when integrated with other adaptation approaches on the same property. The publicity may have helped motivate other land managers to design and implement their own forest adaptation efforts, from integrating climate change into forest management plans to site-specific on-the-ground projects. Among the broader public, it has been perceived as a forward-thinking example of how forestry can respond to climate change. People who might not otherwise show interest in forest management have reached out to express support or participated in tours to learn more about this clearly proactive effort to help forests in the face of climate change. The most valuable legacy of Providence Water's Tunk Hill adaptation planting may be in inspiring and informing future projects.

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Data availability Data and materials available from the lead author upon request.

Declarations

Competing interests N/A.

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