Unionville Barrens, ChesLen Preserve

Climate Change Vulnerability Assessment for the Natural Lands Climate Adaptation Project

This document represents an evaluation of climate change vulnerability for the Unionville Barrens in the Natural Lands' ChesLen Preserve in Chester County, Pennsylvania. The following information was based on expert input provided in fall 2022 as well as sources from the scientific literature.

Habitat Description

The Unionville Barrens are located in in Chester County, Pennsylvania, and are distributed across a 114-acre area of serpentine soils (*1*, *2*). Much of that area (90 acres) is protected in the southeast section of the ChesLen Preserve, owned by Natural Lands; however, a little over 23 acres is privately owned (*1*, *3*). The site is underlain by ultramafic rock that weathers to form serpentine soil with distinctive chemical and physical properties, including extreme deficiencies of macronutrients required by plants (e.g., phosphorus, potassium, calcium) and high concentrations of magnesium and heavy metals such as nickel (*4*). These properties result in harsh conditions that restrict plant establishment and growth, so vegetation cover in serpentine communities is often sparse compared to surrounding ecosystems. Plant communities are characterized by species that are poor competitors in more productive soils, but have unique physiological adaptations to cope with extreme calcium deficiency and magnesium toxicity (*4*, *5*).

The Unionville Barrens are characterized by grasslands and gravel/forb communities comprised of a mix of prairie grasses and serpentine specialists, as well as scattered stands of post oak (*Quercus stellata*) and several other species such as blackjack oak (*Q. marilandica*), dwarf chinkapin oak (*Q. prinoides*), black oak (*Q. velutina*), and eastern redcedar (*Juniperus virginiana*) (*1*, *6*). Open areas were historically maintained through a combination of frequent fire and grazing that limited forest succession, but lack of disturbance since the mid-twentieth century resulted in encroachment that has significantly reduced the area of serpentine grasslands (*1*, *6*). Current management on the site is focused on removal of encroaching trees and invasive shrubs such as autumn-olive (*Elaeagnus umbellata*) as well as restoring disturbance regimes (e.g., through the use of prescribed fire and mowing) and reintroducing native species, with the goal of restoring serpentine grasslands (*1*).

Vulnerability Ranking

Moderate Vulnerability

Moderate Confidence

Vulnerability is evaluated by considering the habitat's sensitivity and exposure to various climate and non-climate stressors as well as the habitat's adaptive capacity or ability to cope with these stressors with minimal disruption. The overall vulnerability of the habitat is ranked on a scale from low vulnerability (dark green) to high vulnerability (yellow). The confidence in the vulnerability ranking's accuracy is similarly ranked on a scale from low (light blue) to high (dark blue).

The Unionville Barrens are dominated by serpentine grasslands that are sensitive to changes in precipitation patterns and increased drought, which impact water stress and have the potential to alter competitive dynamics within species assemblages. Climate-driven changes in disturbance regimes such

as wildfire may have negative impacts on isolated populations of rare species, but have the potential to benefit serpentine grasslands by limiting encroaching vegetation and helping to maintain open areas. The Unionville Barrens is also vulnerable to non-climate stressors such as invasive species and fire suppression/exclusion, which shift species composition and further fragment or degrade the habitat.

Species	Trend
Black oak (*Quercus velutina*)	▲
Blackjack oak (*Quercus marilandica*)	▲
Eastern redcedar (*Juniperus virginiana*)	▲
Post oak (*Quercus stellata*)	▲

Table 1. Likely climate-driven changes in future abundance of individual tree species (see Appendix 1 for more detail).

Like all serpentine ecosystems, the extent of the Unionville Barrens is limited by the area of underlying ultramafic rock, and significant declines over the past several decades have further reduced habitat integrity and opportunities for species migration in response to climate change. The Unionville Barrens supports high levels of biodiversity, including many rare serpentine specialist plants. However, it is likely that some rare species have already been extirpated from the site, and rare species with small ranges and isolated populations are more vulnerable to climate stressors and extreme events. Overall, serpentine ecosystems are relatively resilient to changing environmental conditions and disturbances due to the stress-tolerant traits of characteristic plant species, though plant communities on degraded sites are less able to resist encroachment by generalist species, including invasives. Although climate-informed management of serpentine ecosystems is complicated by limited understanding of how systems in the eastern U.S. might respond to climate change, actions focused on maintaining and/or restoring native plant communities and key ecosystem processes (i.e., removing encroaching species and invasive plants, restoring frequent fire) are likely to increase the ability of the Unionville Barrens to cope with climate stressors and extreme events.

Sensitivity and Exposure

Moderate Impact 

Moderate Confidence 

Sensitivity *is a measure of whether and how a habitat is likely to be affected by a given change in climate and climate-driven factors, changes in disturbance regimes, and non-climate stressors. By contrast,* ***exposure*** *is a measure of how much change in these factors a resource is likely to experience. Sensitivity and exposure are combined here for a score representing climate change impact, with high (yellow) impact scores corresponding to increased vulnerability and low (dark green) scores suggesting a habitat is less vulnerable to climate change.*

Sensitivity and future exposure to climate and climate-driven factors

 

Climate Stressor	Trend	Projected Future Changes[1]
Precipitation	▲	• 5% increase in average annual precipitation (to 48.4 in) in Chester County by 2050; 12% increase (to 5.6 in) by 2100 (*7*) • Most precipitation increases will occur in winter and spring rainfall, with little to no change from historical patterns in the summer and fall (*8*)
Drought	▲	• Likely increases in drought frequency and severity due to higher temperatures that increase evaporation and plant transpiration (*8*)

- **Changes in precipitation amount and timing** and **increases in drought** have the potential to impact the reproduction and distribution of serpentine specialists (*9*), although less is known about how serpentine communities in the eastern U.S. might respond compared to those in the West where the majority of research has been done. Generally, changes in patterns of water stress are known to alter competitive dynamics on serpentine soils, with wetter conditions allowing greater encroachment of both invasive species and non-serpentine native species, particularly in degraded areas (*10*). By contrast, drier conditions and periods of drought tend to limit the establishment of invasives such as Japanese stilt grass (*Microstegium vimineum*) (*11*) and maintain open conditions, favoring the persistence of serpentine specialists (*12–14*). However, extreme drought conditions may exceed critical thresholds, resulting in declines in species richness and diversity (*12*, *13*).

  Changes in patterns of precipitation and drought may also impact the Unionville Barrens if they drive mismatches in plant flowering timing and pollinator migrations or life cycles, which can reduce seed set and successful recruitment for serpentine plants that are insect pollinated (*15*, *16*).

[1] Note that the projections summarized here are based on the RCP 8.5 (high emissions) scenario, which is recommended for planning purposes. Additional details and some projections for the RCP 4.5 (moderate emissions) scenario are provided in the document titled "Overview of Climate Trends and Projections for Natural Lands Preserves", available at https://ecoadapt.org/goto/Natural-Lands.

Sensitivity and exposure to climate-driven changes in disturbances

Disturbance Regimes	Trend	Projected Future Changes
Wildfire	▲	• Likely increased risk of wildfire due to hotter summer temperatures and moisture deficits (*17*)

- **Increases in wildfire activity** over the coming century have the potential to promote the continued dominance of serpentine grasslands, as frequent fire (i.e., through cultural burning by area tribes) played an important role in preventing forest succession and maintaining shallow soils that give native serpentine vegetation a competitive advantage(*6*, *18*). However, even fire-adapted communities such as serpentine barrens may be vulnerable to uncharacteristically frequent and/or severe fires. These have the potential to negatively impact small, isolated populations of rare native species, particularly where the presence of very few individuals leaves them vulnerable to extirpation(*19*). Depending on the timing, wildfires may also damage restoration sites, increasing the cost and effort required to expand serpentine grasslands on the site(*3*).

Sensitivity and current exposure to non-climate stressors

Non-climate stressors can exacerbate habitat sensitivity to changes in climate factors and disturbance regimes, primarily by altering species composition and competitive dynamics.

- **Invasive species** are one of the most significant management concerns in the Unionville Barrens, displacing native serpentine species and altering soil conditions and site microclimate (i.e., by increasing soil depth and shade) in ways that further promote the establishment of invasive and non-serpentine native species (*20*). It is highly likely that changes in precipitation patterns, increases in drought, and warmer temperatures will drive shifts in competitive dynamics on the site, with wetter conditions potentially enhancing the risk of invasion and drier conditions or drought potentially helping to maintain the dominance of serpentine specialists that are well-adapted to harsh growing conditions of the serpentine barrens (*10*, *11*). Generally, already-degraded areas are more vulnerable to invasion, suggesting that continued restoration may increase the resistance of the system to increases in non-native species establishment associated with increased annual precipitation (*10*).
- **Fire suppression and exclusion** has contributed to the encroachment of non-serpentine plants (including many invasive species) into the Unionville Barrens, which until the mid-twentieth century were sustained by frequent fire in addition to grazing and other natural disturbances that limiting conifer encroachment (*6*, *21*). Following the loss of tribal burning and increase in fire suppression as the area became more built, there was a significant loss of habitat extent (*6*). Over the coming century, increases in periods of drought may limit the ability of land managers to conduct prescribed burns by reducing the periods when burn conditions are considered safe (*3*).

Adaptive Capacity

Moderate Adaptive Capacity 

High Confidence 

Adaptive capacity *is the ability of a habitat to accommodate or cope with climate change impacts with minimal disruption. High adaptive capacity (dark green) corresponds to lower overall climate change vulnerability, while low adaptive capacity (yellow) means that the habitat will be less likely to cope with the adverse effects of climate change, thus increasing the vulnerability of the habitat.*

Habitat extent, integrity, continuity, and barriers to dispersal

The extent of the serpentine plant communities such as those found in the Unionville Barrens is limited by the area of the ultramafic bedrock outcrop that creates the unique geophysical conditions that support them (*5*). This results in disjunct, naturally-isolated ecosystems analogous to habitat islands (*22*, *23*). Because populations of highly-specialized serpentine plants are disconnected from one another, there is little opportunity for dispersal and gene exchange, particularly for those that lack specific adaptations for long-distance seed dispersal (*14*, *24*). This limits the potential for range shifts in response to climate change, increasing the risk of local extinction (*25*, *26*). Significant declines in habitat extent over the past several decades (*6*) have further reduced population size and connectivity for rare species such as serpentine specialists, limiting potential migration in response to climate change even more (*24*).

The loss of disturbance regimes that maintain open serpentine grasslands have also impacted habitat integrity (*6*), resulting in greater encroachment of non-serpentine species (including many invasives) that increase soil depth and alter soil chemistry (e.g., pH) which then reduces the competitive advantage that allows serpentine specialists to persist on the site (*6*, *20*).

Habitat diversity

The unique substrate and harsh growing conditions characteristic of serpentine grasslands, together with their naturally-fragmented distribution across the landscape, has resulted in high levels of genetic divergence and endemism within these ecosystems (*5*, *22*). As a result, they typically support high levels of biodiversity, including rare serpentine specialist plants. This is the case in the Unionville Barrens, where at least 20 endangered, threatened, or rare species have been recorded (*6*). These include the globally-threatened serpentine aster (*Symphyotrichum depauperatum*), which is found only in serpentine barrens in Pennsylvania and Maryland. While no systematic inventory of animal species has been done on the site, at least two rare invertebrates have been documented (*6*). In heavily-forested areas such as southeastern Pennsylvania, serpentine grasslands also provide habitat for declining grassland birds such as the prairie warbler (*Dendroica discolor*) (*6*).

It is highly likely that native species diversity in the Unionville Barrens has already declined due to degradation and loss of the serpentine grasslands, and a number of rare species have already been extirpated from the site (*6*). Those that remain are highly vulnerable to further habitat loss as a result of forest succession and encroachment of non-native species (*6*), and declining populations of species with small ranges and isolated populations are at greater risk of extirpation due to climate stressors and extreme events such as wildfire or drought (*19*).

Resistance and recovery

Serpentine ecosystems such as the Unionville Barrens are relatively resilient to changing climatic conditions and disturbances, as characteristic species have many stress-tolerant traits that allow them to outcompete more generalist species in the harsh growing conditions typical of serpentine soils (*10*, *12*). However, on fragmented or degraded sites, serpentine plant communities are less able resist encroachment and invasion by non-native species (*27*, *28*), which can then result in changes in site conditions (e.g., soil depth and pH) that allow further encroachment and eventually result in conversion of the barren ecosystem to woodlands (*6*).

Management potential

The Unionville Barrens represent a significant natural resource, and are considered a conservation priority both within the preserve and more broadly as they represent a globally rare serpentine barren community (*2*, *6*, *29*). There are few, if any, advocacy groups focused on serpentine barrens in the eastern U.S. (*3*), and there is relatively little scientific understanding of serpentine ecosystems in the region compared to those in the western U.S. (*5*). Despite this, local scientific interest is significant which is likely to increase support for climate-informed management on the site (*3*). Regulatory support for the protection of rare species also exists (e.g., through state and federal endangered species regulations) (*30*).

Management of serpentine ecosystems such as the Unionville Barrens is complicated by limited understanding of how serpentine systems in the eastern U.S. might respond to climate change. Continuing to restore native plant communities and key ecosystem processes (i.e., by removing encroaching species and non-native plants and restoring disturbance regimes) is likely to become even more important in the context of climate change, as serpentine species within intact, high-quality ecosystems exhibit a greater ability to resist stressors such as increased drought and invasion by non-native species (*10*, *30*). It will also be critical to consider the identification of potential microrefugia (i.e., areas where vegetation or small-scale topographic features may result in less extreme changes compared to surrounding areas) as these will be critical to the persistence of rare and endemic serpentine species (*26*). Finally, limiting public access to the site will remain important to avoid the negative impacts of overuse (e.g., trampling), though public education to increase awareness of this unique ecosystems may also play a role in building societal support for climate-informed management (*3*).

Recommended Citation

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Further information on the Natural Lands Climate Adaptation Project is available on the project page (https://ecoadapt.org/goto/Natural-Lands).

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Appendix 1. Climate Change Projections for Individual Tree Species

Although vegetation cover on the Unionville Barrens is primarily comprised of serpentine grasslands and gravel/forb communities, there are scattered stands of oak and eastern redcedar. Projected trends in the distribution and abundance of these species, compiled by the Northern Institute of Applied Climate Science, suggest that all are likely to expand within the Piedmont region of Pennsylvania, which includes Chester County and ChesLen Preserve (*31*).

Table 1. Adaptability, abundance, habitat change, and capability of tree species in the Unionville Barrens habitat under RCP 4.5 and 8.5 conditions. *Source: NIACS Climate Change Projections for Individual Tree Species in Pennsylvania* (*31*).

			LOW CLIMATE CHANGE (RCP 4.5)		HIGH CLIMATE CHANGE (RCP 8.5)	
SPECIES	ADAPTABILITY	ABUNDANCE	HABITAT CHANGE	CAPABILITY	HABITAT CHANGE	CAPABILITY
Black oak	o	o	▲	△	▲	△
Blackjack oak[2]	+	–				
Eastern redcedar	o	o	▲	△	▲	△
Post oak[3]	+	–				

Table 2. Summary of ranking definitions and categories for adaptability, abundance, habitat change, and capability, used to evaluate tree species in Pennsylvania. *Source: NIACS Climate Change Projections for Individual Tree Species in Pennsylvania (*31*).*

ADAPTABILITY	ABUNDANCE
Life-history factors that are not included in the Tree Atlas model but may impact species ability to adapt (e.g., ability to respond favorably to disturbance)	Based on Forest Inventory Analysis summed Importance Value data, calibrated to a standard geographic area
+ **High:** Species may perform better than modeled	+ **Abundant**
– **Low:** Species may perform worse than modeled	– **Rare**
o **Medium**	o **Common**
HABITAT CHANGE	**CAPABILITY**
Projected change in suitable habitat between current and potential future conditions	Overall rating that describes species' ability to cope or persist with climate change based on suitable habitat change class, adaptability, and abundance in the region
▲ **Increase:** Projected increase of >20% by 2100	△ **Good: I**ncreasing suitable habitat, medium or high adaptability, and common or abundant
▼ **Decrease:** Projected decrease of >20% by 2100	▽ **Poor:** Decreasing suitable habitat, medium or low adaptability, and uncommon or rare

[2] A natural hybrid of black oak and blackjack oak is present in the barrens, *Quercus x bushii*.

[3] Post oak is present on the site, but in very low numbers (population is limited to 10 -20 individuals).