Mature Forest, Bear Creek Preserve

Climate Change Vulnerability Assessment for the Natural Lands Climate Adaptation Project

This document represents an evaluation of climate change vulnerability for mature forest habitats in the Natural Lands' Bear Creek Preserve in Luzerne 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 Natural Lands' Bear Creek Preserve is located in Luzerne County, Pennsylvania, and occupies a total of 3,565 acres. About 80% of that area is mature forest, which is primarily dominated by hemlock-mixed hardwood palustrine forest and white pine riparian communities (*1*). Mature forest habitats are comprised of large overstory trees, shade-tolerant seedlings, saplings, and other understory trees and shrubs. Within the preserve, areas of mature forest are interspersed with younger forests (including roughly 70 acres that have been thinned to create early-successional habitat), shrublands, and herbaceous wetlands, as well as a pipeline corridor (*1*).

The hemlock-mixed hardwood palustrine forest is located along parts of both Shades and Bear Creeks. Eastern hemlock (*Tsuga canadensis*) makes up 25-75% of the canopy cover species for this forest type. Associated species include eastern white pine (*Pinus strobus),* red oak (*Quercus rubra*), yellow birch (*Betula alleghaniensis*), red maple (*Acer rubrum*), Tamarack (*Larix laricina*), Blackgum (*Nyssa sylvatica*), and Black ash (*Fraxinus nigra*). Rosebay (*Rhododendron maximum*) often forms a dense understory and the herbaceous layer includes false hellebore (*Veratrum viride*) and marsh marigold (*Caltha palustris*) (*2*). This habitat contains rare and vulnerable plant species including few-seeded sedge (*Carex oligosperma)* (*1*). The white pine riparian habitats are primarily located in the Shades Creek Tract of the preserve and are dominated by eastern hemlock and eastern white pine. Yellow birch, red maple, and black/sweet birch (*Betula lenta*) are present in small numbers. Serviceberry (*Amelanchier spp.*) is common and mountain laurel (*Kalmia latifolia*), and blueberry species (*Vaccinium spp.*) are present in the understory (*2*).

The mature forest habitat is classified as a combination S3 (vulnerable – on the order of 21-100 occurrences statewide) and S4 (apparently secure – >100 occurrences statewide) community by the Pennsylvania Natural Diversity Inventory (PNDI) of the Pennsylvania Natural Heritage Program (PNHP, meaning they are considered to be generally uncommon and potentially vulnerable to extirpation (*2*, *3*).

Vulnerability Ranking

Moderate Vulnerability

High Confidence

The overall vulnerability of the habitat is ranked on a scale from low vulnerability (dark green) to high vulnerability (yellow). 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 confidence in the vulnerability ranking's accuracy is similarly ranked on a scale from low (light blue) to high (dark blue).*

Mature forests are sensitive to changes in climate stressors such as altered patterns of precipitation and soil moisture, increased drought, reduced snowfall and earlier snowmelt, and altered stream flows. These changes have the potential to impact water availability and flooding regimes within riparian areas where many mature forests in Bear Creek Preserve are located, potentially affecting seedling establishment and survival, understory species composition, and forest vulnerability to insect pests and disease. Climate-driven changes in disturbance regimes (e.g., wildfire, insects and disease, extreme storms, and flooding) also have the potential to alter habitat species composition (e.g., by impacting overstory species establishment as seedlings/saplings), as well as structure and function. Finally, mature forests in Bear Creek Preserve are susceptible to non-climate stressors such as invasive and problematic species, pollution/poisons, roads, highways, trails, and recreation. These stressors can exacerbate habitat sensitivity to changes in climate factors and disturbance regimes by altering species composition, degrading the ecosystem, and disrupting habitat connectivity.

Mature hemlock-mixed hardwood palustrine forests are uncommon, and most of the species within mature forests in Bear Creek Preserve are projected to decline over the coming century, suggesting that reduced productivity and shifts in species composition are likely to occur. Eastern hemlock and eastern white pine, in particular, are projected to undergo growth declines and a loss of climatically suitable habitat over the coming decades (*4*, *5*). Most of the preserve consists of contiguous forest habitat, but the hemlock-mixed hardwood palustrine mature forest community is restricted to riparian areas. There is support to manage or cope with the impacts of climate change, but the actual management of this habitat may be difficult due to its fragmented distribution within the preserve. Management actions that could help build adaptive capacity could include those that mitigate erosion, prevent pollution, decrease/prevent habitat alteration, and manage invasive species, pests, and diseases.

Species	**Trend**
Black ash *(Fraxinus nigra)*	▼
Black/sweet birch *(Betula lenta)*	▼
Blackgum *(Nyssa sylvatica)*	▲
Eastern hemlock (*Tsuga canadensis*)	▼
Eastern white pine (*Pinus strobus*)	▼
Red maple *(Acer rubrum)*	▼ *Reduced climatic suitability but highly adaptable*
Red oak *(Quercus rubra)*	▲
Serviceberry (*Amelanchier spp*.)	▼
Tamarack *(Larix laricina)*	▼
Yellow birch *(Betula alleghaniensis)*	▼

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

Sensitivity and Exposure

Moderate Impact

High 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 exposure to climate and climate-driven factors

Climate Stressor	Trend	Projected Future Changes[1]
Precipitation	▲	• 5% increase in average annual precipitation (to 46.5 in) in Luzerne County by 2050; 12% increase (to 5.5 in) by 2100 (*6*) • Most precipitation increases will occur in winter and spring rainfall, with little to no change from historical patterns in the summer and fall (*7*)
Soil moisture	▲ ▼	• Overall trend towards decreased soil moisture by 2100 (*7*) • Likely increases in spring soil moisture and decreases in summer and fall soil moisture (*7*)
Drought	▲	• Likely increases in drought frequency and severity due to higher temperatures that increase evaporation and plant transpiration (*7*)
Snowfall, snowpack & snowmelt	▼	• Decrease in annual average snowfall and number of days when snowfall occurs by 2100, resulting in reduced snow cover extent, snowpack depth, and duration (*7*, *8*) • Overall trend toward earlier snowmelt in the year, largely due to warmer temperatures and increased rainfall (*7*)
Streamflow	▲ ▼	• Higher winter stream flows due to shifts towards a greater proportion of winter precipitation occurring as rain (*4*) • Decreased stream volume during warm months and ~18% increase in the length of the low-flow season in the Mid-Atlantic region by 2050 (*9*)

- **Increased precipitation amounts**, **changes in soil moisture**, and **more frequent/severe droughts** are likely to impact hydrologic regimes as well as the growth and establishment of plant communities in mature forests. Changes in the seasonality and precipitation patterns within a forest can impact its structural complexity (e.g., forest biomass and canopy height) by altering water availability and soil moisture and thus impacting the growth of canopy and understory species (*10*, *11*). However, mature trees are generally less sensitive to the fluctuating water availability (i.e., altered patterns of precipitation and drought) than seedlings/younger trees. More frequent droughts (accompanied by hotter temperatures) will

[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.

cause increased rates of evaporation and plant transpiration, reducing soil moisture and water table levels (*7*, *8*). These reductions in water availability could impact the establishment and survival of understory species, which tend to have more shallow, limited root systems that make them more vulnerable to drought stress (*12*). Prolonged instances of drought stress could also increase mature trees' susceptibility to insects or disease (*4*, *12*).

- **Decreased snowfall/snowpack** and **earlier snowmelt** are a result of increased warming trends, which result in a smaller proportion of winter precipitation falling as snow (*4*). Earlier snowmelt timing has been linked to a decrease in summer ecosystem productivity due to its connection to increased seasonal drought (*13*). A decreased snowpack can increase instances of root damage due to a change in soil freezing and thawing. For mature trees that have deeper, more established root systems, this may be less of a detrimental factor compared to younger tree and plant species that have shallow roots. For mature hemlock palustrine forest and white pine riparian habitats along Shades and Bear creeks, earlier snowmelt could result in higher flows that lead to increased erosion and downstream sediment transfer, and start an earlier reproductive season for riparian species (*13–15*).

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 (*16*)
Insects & disease	▲	• Increased occurrence of insect outbreaks and spread of disease (*4*, *17*)
Extreme storms & flooding	▲	• Increase in magnitude, frequency, and intensity of extreme precipitation events and associated flooding (*7*) • Increase from 0.5 to 0.9 days per year with >2" precipitation (+80%) in Luzerne County by 2100 (*6*)

- **More frequent wildfires** can lead to greater tree mortality, reduced forest productivity, and shifts in species composition as sensitive/fire-intolerant species (e.g., maple) decline and there are increased opportunities for colonization of more fire-tolerant species (e.g., oak and pine) (*1*, *18*). Mature forests, however, may have an advantage compared to younger forests as they tend to be less sensitive to mortality from wildfires. Mature forests generally have cooler, moister soils (*19*), and larger trees tend to be more fire- resistant due to thicker bark and deep roots (*20–23*) that provide physical protection. However, many dominant species (e.g., eastern hemlock, yellow birch, red maple, tamarack, and black ash) in mature forest habitats of the preserve, with the exception of white pine and blackgum, are sensitive to fire due to relatively thin bark and shallow roots of these species compared to more fire-tolerant species (*1*, *24–28*).
- **Increases in insect pests and diseases** are likely to alter the forest's structure and function (*18*) by contributing to tree mortality, reducing tree growth, and compounding the damage caused by climate stressors (*4*, *17*, *29*). Insect pests and diseases have the potential to kill many trees within one habitat , inducing a decline that would impact the wildlife populations that depend on those species while also impacting nutrient cycling, tree growth, and regeneration (*30*).

Insects are temperature-sensitive, and projected temperature increases could quicken their development and generation time and lead to range shifts (*30*–*32*). Climate change stressors such as drought can also modify a tree's defense mechanisms against insect pests and disease, making the damage from infestation more severe (*1*, *4*, *17*). The mature hemlock-mixed hardwood palustrine forests within Bear Creek Preserve are dominated by eastern hemlock, which is threatened by the hemlock woolly adelgid (*Adelges tsugae*). An infestation of hemlock woolly adelgid leads to tree needle loss, branch dieback, disruption of nutrient transfer, and ultimately death within about 10 years from infestation (*4*, *33*–*35*). This pest is highly influenced by temperature and is likely to expand its range and increase in numbers as temperatures increase (*29*).

- **Increases in the occurrence of extreme storms and flooding** are likely to impact the forest's composition, integrity, and regeneration. Extreme wind events can cause damage to older trees through breakage and uprooting, and eastern hemlock, in particular, is prone to windthrow (*3*). Mature, established trees are generally more tolerant of flooding as compared to seedings, but can also experience damage under more extreme conditions. Although most mature forests in Bear Creek Preserve occur on riparian soils that may become saturated during and after storm events (*36*), more periods of prolonged flooding can reduce the growth and survival of species not adapted to these conditions (e.g., blackgum, eastern white pine, eastern hemlock, red oak, black cherry) by damaging root systems and diminishing oxygen availability (*37*–*39*). By contrast, flood-tolerant species (e.g., red maple, black ash, tamarack) usually are able to regenerate/produce new roots after a flooding event and are adapted to withstand various depths of the water table and decreased oxygen supply during periods of water inundation (*24*, *40*). Extreme flooding also has the potential to reduce water quality where increased runoff and contaminants enter the habitat from nearby roads (*41*).

Sensitivity and current exposure to non-climate stressors

Non-climate stressors can exacerbate habitat sensitivity to changes in climate factors and disturbance regimes by altering species composition, degrading the ecosystem, and disrupting habitat connectivity.

- **Invasive and problematic species** can alter the abundance and diversity of native species through competition for resources, increased predation risk, and/or disease spread (*42*). Invasive species present in Bear Creek Preserve include Japanese barberry (*Berberis thunbergia*), Japanese knotweed (*Fallopia japonica*), Japanese stiltgrass (*Microstegium vimineum*), and multiflora rose (*Rosa multiflora*). While invasive plants are not a large issue in the habitat now and have been addressed by preserve managers, they could become more problematic as temperatures rise and more invasive species are able to move north into Pennsylvania's southeastern forests (*1*).
- **Pollution/poisons** such as pesticides, excess nutrient input, and heavy metals can degrade groundwater quality (*43*). Within Bear Creek Preserve, pollutants have the potential to enter the groundwater tributaries in the mature forest habitats from both Bear Creek and Shades Creek, which both run alongside or through the preserve (*1*).
- **Roads, highways, and trails** can increase stormwater runoff, disperse pollutants, and facilitate the spread of invasive species through soil disturbance and seed transport on vehicles and

recreational users (*44*, *45*). Roadways and trails can also act as barriers to dispersal for species seeking refuge from climate impacts.

- **Recreation** such as hiking, guided nature tours, and birdwatching are allowed on the Bear Creek preserve. While these passive activities do not have major impacts on the system, excessive recreation via ATV and foot trail systems (or the creation of rogue trails where people go off trail in the preserve) could lead to compacted soils, decreasing porosity and water availability in the soils. This could impact rooting depth/restrictions, nutrient availability, and soil productivity (*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

Most of Bear Creek Preserve consists of contiguous mature forest habitat with the exception of the Williams Transcontinental and Buckeye gas pipelines and areas that were logged and thinned to create early successional habitat (*1*). Additionally, there are a few roads, a trail network, and the Francis E. Walter Dam nearby. Despite the presence of these areas, they represent only a small portion of the Preserve and mature forest habitat is considered extensive and relatively continuous. The preserve is surrounded by state forests, Pennsylvania game lands, Army Corp of Engineers protected areas, and properties that hold conservation easements, all of which help to protect the preserve and create a natural barrier to outside stressors.

The mature forest habitat within the preserve remains largely intact, healthy, and has good ecological integrity (*1*). Forest age can strongly influence the ecological integrity of habitat and older age has been connected to a more stable forest structure and higher integrity as compared to younger forests (*46*).

Habitat diversity

Generally, mature forests have been linked to high structural diversity, species richness, and biomass as compared to younger forests (*47*, *48*). Mature forests tend to be composed of unevenly aged stands of different sizes, which add to the complexity of the forest structure and have been linked to high forest productivity (*47*, *49*). Mature forests with minimal disturbance and varying stand ages are also linked to higher species diversity and abundance compared to younger forests (*48*). This is due in part to the partially open canopy of most mature forests, which allows development of shade-tolerant and shade-intolerant species in the understory. The hemlock-mixed hardwood palustrine forest is moderately diverse and uncommon with concerns for long-term decline. The dominant species (eastern hemlock) is the most sensitive component of this community. Although it is under stress from woolly adelgid infestation statewide, the eastern hemlock does not have any special listing at this time (*1*).

Resistance and recovery

As the dominant species within most of Bear Creek Preserve's mature forests, eastern hemlock is a long-lived, but slow-growing species. Stress due to climate change in conjunction with a woolly adelgid infestation could potentially generate a dieback event within the contiguous communities of eastern hemlock in the Bear Creek preserve (*29*, *35*). Depending on the severity of climate change effects, community dominance would likely shift towards more drought-adapted species (e.g., maple, birch, white pine) or be absorbed into the surrounding oak-dominated community (*1*). Generally, larger and mature trees tend to be more resistant to drought, fire, and other stressors as compared to younger trees due to their extensive root systems.

Management potential

Bear Creek Preserve is a popular hiking area utilized by the public as well as for guided nature hikes and educational opportunities with local colleges and grade schools. Forested areas within the preserve are also valued for their role in maintaining high-quality water resources that support native trout populations and contribute to public water supplies for cities downstream (*1*). Protection of mature forests within Bear Creek Preserve and the surrounding area is well-supported by the Pennsylvania Department of Environmental Protection, Pennsylvania Department of Conservation and Natural Resource, Pennsylvania Game Commission, Army Corps of Engineers, and regional land conservancies. As a result, Bear Creek Preserve remains well-funded and Natural Lands is frequently awarded grants for site maintenance and restoration (*1*). Taken together, these factors suggest a strong interest in protecting and maintaining mature forests, both in the region as well as within Bear Creek Preserve specifically, and increase the likelihood of broad support for climate-informed management.

Despite the presence of sufficient funding and staff time, climate change is likely to increase management challenges, particularly for more fragmented habitat types such as hemlock-mixed hardwood palustrine forests. For example, climate-driven increases in woolly adelgid may make treatment for the invasive pest cost-prohibitive. Increased focus may also need to be placed on reducing wildfire risk around these communities (*1*). Additional activities that may reduce climate vulnerability include promoting high species diversity and complex forest structure within both the canopy and understory, which increases forest resilience to environmental stress and disturbances (*50*). Continuing to implement invasive species control and reduce the spread of introduced pests and pathogens will also play an important role in supporting healthy forests, particularly as climate change accelerates the spread and establishment of both existing threats and introduces new ones (*50*).

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

Table 1. Adaptability, abundance, habitat change, and capability of tree species in Bear Creek Preserve's mature forest habitat under RCP 4.5 and 8.5 conditions. *Source: NIACS Climate Change Projections for Individual Tree Species in Pennsylvania* (*5*).

			LOW CLIMATE CHANGE (RCP 4.5)		HIGH CLIMATE CHANGE (RCP 8.5)	
SPECIES	**ADAPTABILITY**	**ABUNDANCE**	**HABITAT CHANGE**	**CAPABILITY**	**HABITAT CHANGE**	**CAPABILITY**
Black ash	–	–	▼	▽	▼	▽
Black/sweet birch	–	+	▼	▽	▼	▽
Blackgum	+	○	▲	△	▲	△
Eastern hemlock	–	○	▼	▽	▼	▽
Eastern white pine	–	○	▼	▽	▼	▽
Red maple	+	+	▼	△	▼	△
Northern red oak	+	+	●	△	●	△
Serviceberry	○	–	▼	▽	▼	▽
Tamarack	–	–	▼	▽	▼	▽
Yellow birch	○	–	▼	▽	▼	▽

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 (*5*).*

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**
○	**Medium**	○	**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:** Increasing 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
●	**No change**	○	**Fair:** Mixed combinations, such as a rare species with increasing suitable habitat and medium adaptability