EcoAdapt

Spruce Swamp, Bear Creek Preserve

Climate Change Vulnerability Assessment for the Natural Lands Climate Adaptation Project

This document represents an evaluation of climate change vulnerability for spruce swamp 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. Spruce swamp/palustrine woodland habitats are present in two locations of parcel C of the preserve, including (1) the southwest section of the preserve off of Whitehaven Road which covers about 40 acres, and (2) an 8-acre parcel in an upland depression along the west boundary of south Route 115 (*1*, *2*). The habitat is classified as an S3 community by the Pennsylvania Natural Diversity Inventory (PNDI) of the Pennsylvania Natural Heritage Program (PNHP), meaning it is rare and vulnerable and is only found on the order of 21-100 occurrences statewide (*3*). These forested wetlands tend to occur at higher elevations and in poorly drained basins with acidic and low to moderate nutrient availability. Spruce swamp wetlands are important hydrologic features that store water during high precipitation events and release it slowly to maintain baseflow in the Lehigh River watershed (*2*).

In Bear Creek Preserve, the spruce swamp habitat is dominated by red spruce (*Picea rubens*) and red maple (*Acer rubrum*), bryophytes (e.g., *Sphagnum spp., Dicranum spp., Pleurozium schreberi*), a variety of sedge species (e.g., *Carex folliculata*, *Carex spicata, Carex trisperma, Carex paupercula, carex echinata*), and a shrub layer compromised of highbush blueberry (*Vaccinium corymbosum*), mountain laurel (*Kalmia latifolia*), witch hazel (*Hamamelis spp.*), serviceberry (*Amelanchier arborea*), winterberry (*Ilex verticillate*), and sheep laurel (*Kalmia angustifolia*) (*1*, *4*). The understory herbaceous layer includes cinnamon fern (*Osmunda cinnamomea*), royal fern (*Osmunda regalis*), tawny cotton-grass (*Eriophorum virginicum*), marsh marigold (*Caltha palustrris*), water arum (*Calla palustris*), swamp candles (*Lysimachia terrestris*), round-leaved sundew (*Drosera rotundifolia*), goldenrods (*Solidago spp.*) and others (*1*, *4*). Additional tree species present include eastern white pine (*Pinus strobus*), eastern hemlock (*Tsuga canadensis*), pitch pine (*Pinus rigida*), American larch (*Larix laricina*), blackgum (*Nyssa sylvatica*), and yellow or swamp birch (*Betula alleghaniensis*) (*1*, *4*). In this type of habitat, the conifer tree species contribute 25-75% of the canopy and canopy closure is generally less than 60 percent (*5*).

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).*

Spruce swamps are sensitive to changes in nutrient input, hydrologic and thermal regimes. These habitats are vulnerable to climate stressors and disturbances including changes in precipitation (amount/timing), soil moisture, heat waves, increased drought, and freshwater temperature. These changes are likely to disrupt species composition and habitat suitability by impacting wetland hydroperiod, water levels, and water quality. Climate-driven changes in disturbances regimes (e.g., increased risk of wildfires, extreme flooding, and storm events) also contribute to the future vulnerability of the habitat. Spruce swamps in this region are also vulnerable to non-climate stressors such as invasive and problematic species, pollution/poisons, and roads, highways, and trails, and residential or commercial development. These stressors can create water diversions, further fragment or degrade the habitat, and alter species composition and ecosystem function.

The continuity of the spruce swamp habitat within the preserve is relativity moderate as is its physical and topographical diversity. These factors could impact the habitat's adaptive capacity to climate and non-climate stressors by limiting the dispersal potential of flora and fauna and the availability of nearby suitable habitats. Management actions that maintain or restore hydrologic regimes, manage vegetation, protect the watershed, maintain support habitat protection, and reduce nutrient inputs could help to build the adaptive capacity of the spruce swamp habitat.

Species	Trend
Blackgum (*Nyssa sylvatica*)	▲
Red maple (*Acer rubrum*)	▼ *Reduced climatic suitability but highly adaptable*
Eastern hemlock (*Tsuga canadensis*)	▼
Eastern white pine (*Pinus strobus*)	▼
Pitch pine (*Pinus rigida*)	▼
Red spruce (*Picea rubens*)	▼
Serviceberry (*Amelanchier arborea*)	▼
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

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	▲	• 6.1°F increase in average annual temperature in Luzerne County by 2050; 9.6°F increase 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 (*6*)
Soil moisture	▲ ▼	• Overall trend towards decreased soil moisture by 2100 (*6*, *7*) • Likely increases in spring soil moisture and decreases in summer and fall soil moisture (*6*, *7*)
Freshwater temperature	▲	• Overall trend toward increased freshwater temperature during the next century (*6*)
Extreme heat & heat waves	▲	• Increase from 2.3 to 22.5 days per year with high temperatures over 90°F in Luzerne County by 2050, and to 64.1 days per year by 2100 (*8*)
Drought	▲	• Likely increases in drought frequency and severity due to higher temperatures that increase evaporation and plant transpiration (*6*)

- **Increased precipitation amounts**, soil moisture changes, and drought impact hydrologic flows, water availability, and quality in spruce swamp habitats. Increased precipitation and projected changes in snowmelt timing can interfere with some wetland species' reproduction (*9*). Precipitation increases are likely to be particularly significant in the winter months, and a smaller proportion of that is expected to fall as snow. Together with shifts towards earlier snowmelt driven by higher temperatures (*10*), this is expected to disrupt the hydrologic regime in spruce swamp habitats by increasing the duration and amount of flooding during the winter and spring months (*6*). This disruption to the spruce swamp habitat hydrologic regime can cause issues such as the spread of nutrient input from surrounding areas and lowering or raising water tables.

  Forested inland wetlands, such as spruce swamps, typically have saturated soils and are comprised of trees that have adapted to grow in low-oxygen and seasonally flooded environments (*11*). A reduction in soil moisture could impact the opportunity for and success of seed establishment and germination and increase the mortality of shallow-rooting seedlings (*12*, *13*). Projected alterations in water availability will likely shrink the extent of the high-water table, lead to loss of habitat, and possibly result in an invasion of forest communities better suited to drier soils (*2*, *6*). More frequent droughts and hotter temperatures will cause increased evapotranspiration, reduce water availability, and may result in less-frequent flooding during fall months (*6*, *10*). This will lead to drier soils and an opportunity for an increase in wildfire events during this time (*11*). However, increased precipitation during winter

[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.

and spring months could recharge groundwater, assisting in the maintenance of the habitat's hydrologic regime.

- **Warmer freshwater temperatures** may provide a means for invasive/problematic species introductions and increase competition from more thermal-tolerant species. These impacts could reduce the ability of some wetland species to survive and could be exacerbated by altered flow regimes (*14*). For certain plant and invertebrate species, warmer waters may also provide an opportunity for growth and productivity (*9*). Increased water temperature also decreases oxygen solubility and increases respiration rates. These impacts lead to an overall reduction in dissolved oxygen and, consequently, lessened water quality (*6*).
- **More frequent and intense heat waves,** in addition to a general trend in warmer annual temperatures overall, are likely to increase mortality events due to resulting increased evapotranspiration causing water loss and drier soils during these periods (*6*, *7*). As temperatures rise, plant hardiness zones in the region will also shift (*15*). Plant hardiness zone shifts alongside frequent heat waves could impact species composition within the preserve, forcing some wildlife out of their normal home range, changing the ecosystem structure and function, and possibly increasing the risk of invasion (*16*–*19*).

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 (*15*)
Extreme flooding & storms	▲	• Increase in magnitude, frequency, and intensity of extreme precipitation events and associated flooding (*6*) • Increase from 0.5 to 0.9 days per year with >2” precipitation (+80%) in Luzerne County by 2100 (*8*)
Insects & disease	▲	• Increased occurrence of insect outbreaks and spread of disease (*12*, *20*)

- **Increases in wildfire activity** have the potential to significantly alter species composition within spruce swamp habitats, due to low fire tolerance of the dominant species (red spruce and red maple) (*21*, *22*). Wildfire risk is most significant during very dry years and periods of drought when soil moisture is particularly low; under more normal conditions, spruce swamp wetlands have the potential to act as a firebreak.
- **Increases in extreme flooding and storm events** are likely to damage ecosystem structure and function (*10*, *16*). In this habitat, seasonal flooding is common and short periods of submergence and shallow flooding can be tolerated for understory plants. However, a large amount and prolonged duration of flooding can reduce woody wetland plant seedling establishment (delay or inhibit germination), growth (biomass and height), and survival (*23*). Flooding also has the potential to reduce water quality where increased runoff and contaminants enter the wetland from nearby roads (*12*). These factors can impact the species composition of the habitat, favoring those that can adapt to longer periods of inundation. Spruce swamp habitats do, however, provide an important service during flooding events by

capturing and storing floodwaters, which are then released back into the watershed gradually over time. Additionally, the habitat's tree, shrub, and herbaceous species composition help slow the water flow speed, which may minimize or moderate extreme flooding impacts on the watershed (*24*, *25*).

- **Increases in insects (including pests) and diseases (including pathogens)** are relatively likely due to projected temperature increases and the weakened level of defense of the ecosystem due to the impacts of other climate stressors (*12*, *20*). Insects are temperature sensitive physiologically and projected temperature increases could quicken their development and generation time (*26*, *27*). The increased stress that drought causes on spruce swamp species may also make them more vulnerable to the spread of insects and diseases. Elevated plant drought stress, more rapid insect development, accelerated reproduction cycles, and an increase in insect winter survival will play a part in the extent and dispersal of insect and disease outbreaks in a habitat (*14*, *16*, *26*, *27*). Additionally, while the habitat is a natural sink for water storage, increased instances of flooding may overload the habitat's holding capacity. This excess of water can be a conduit for the spread of pathogens (*16*). Insects and diseases can alter habitat and ecological processes by reducing tree vitality, changing species composition, altering ecosystem structure and function, and can lead to tree mortality events. The resulting impacts of an insect or disease outbreak in a habitat can therefore be detrimental to the habitat's ability to adequately respond to future disturbances (*28*). In the Bear Creek Preserve, pests such as forest tent caterpillars, hemlock wooly adelgid, emerald ash borer, and the egg mass of a gypsy moth have been detected. Additionally, beech bark disease and chestnut blight pathogens are also present.

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, water flow, quality, and quantity, and 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 (*29*). Currently, the presence of invasive plant species is minimal in the spruce swamps of Bear Creek Preserve and occurs most frequently near features such as roads, trails, and canopy openings. Invasive species present in Bear Creek Preserve include Japanese barberry (*Berberis thunbergia*) and Japanese knotweed (*Fallopia japonica*) (*1*). In the spruce swamp portions of the preserve, the invasive multiflora rose (*Rosa multiflora*) has been identified[4]. While currently not a major issue, increasing temperatures and drought conditions in the swamp habitat could promote the spread of invasive and problematic species from the surrounding forest (*2*, *17*).
- **Pollution and poisons** such as pesticides, excess nutrient input, and heavy metals can degrade wetland water quality (*30*). Within Bear Creek Preserve, pollutants have the potential to enter spruce swamp habitats from both Bear Creek and Shades Creek, which both run alongside or through the preserve.
- **Roads, highways, and trails** can increase stormwater runoff, disperse pollutants, and facilitate the spread of invasive species by altering habitats (*31*). Roadways can also act as barriers to dispersal for species seeking refuge from climate impacts and limit connections within a

watershed. The presence of roads had also been connected to changes in species composition, ecosystem function, and altered hydrologic processes (*31*, *32*).

- **Land-use conversions to residential and commercial development** can disrupt the natural connectivity of the habitat, promote fragmentation, alter nutrient cycling, and contribute to ecosystem degradation (*33*, *34*). The construction can also be a means of pollutant spread via runoff that could be detrimental to the ecosystem by degrading water quality and habitat. Fragmentation due to development can contribute to disruption in hydrologic regimes through the physical blockage of water flow or redirection to prevent flooding in developed areas. This can lead to habitat loss and affect faunal species that depend on the habitat for shelter and breeding (e.g., amphibians) (*33*). Land-use conversion to residential and commercial developments is not a current threat to the spruce swamp habitat in Bear Creek preserve. Land-use conversion is a possible future threat to the preserve's surrounding areas and may therefore impact the integrity of the habitat later down the line.

Adaptive Capacity

Moderate Adaptive Capacity

Moderate 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 spruce swamp habitat in the Bear Creek Preserve is relatively moderate, occupying about 48 acres of the preserve total of 3,565 acres. However, nearby developmental pressure poses a threat to the habitat's integrity and continuity. While most of the Bear Creek Preserve is considered contiguous because it is surrounded by state forest, Pennsylvania game, and Army Corp of Engineers lands as well as properties that hold conservation easements, spruce swamp habitat continuity is relatively moderate. The habitat within the Bear Creek preserve exists on widely scattered glacial depressions and rare plant communities that depend on the specific glacial geology may have restricted mobility (*2*). It may be difficult for spruce swamp species to adapt to surrounding non-wetland habitat, limiting the dispersal options (*9*, *35*) and the availability of nearby suitable habitats (*36*).

Habitat diversity

The spruce swamp habitats of Bear Creek Preserve have relatively low physical and topographical diversity as well as low diversity in functional groups compared to other surrounding habitats (*2*). The diversity of component species in this habitat is moderate (*2*). However, wetland ecosystems inherently play a transitional role between terrestrial and aquatic systems (e.g., a transition from Shades Creek into the dry oak forest habitat of the preserve) and therefore are often comprised of a variety of different biological communities (*9*).

Resistance and recovery

The spruce swamp has an overall moderate ability to resist and recover from the impacts of stressors/maladaptive human responses (*2*). Compared to surrounding areas, there are lower deer and invasive species levels in the Bear Creek Preserve habitat. Due to less deer grazing in the area, new seedlings have a better chance to grow and replace mature trees that may be damaged or destroyed during a disturbance (*2*).

Management potential

Spruce swamps are important hydrologic features that help to moderate water flow in the local watershed by storing water during high precipitation events and releasing it slowly to maintain baseflow. As a headwater wetland in the Delaware River watershed, the future protection of this habitat would be supported by the Pennsylvania Department of Environmental Protection, Pennsylvania Department of Conservation and Natural Resources, the Pennsylvania Game Commission, the Army Corps of Engineers, and local land conservancies that could help increase future management potential of the area (*2*). Spruce swamps are considered rare systems within the state of Pennsylvania (*3*), and the Bear Creek spruce swamp is a high-quality, protected habitat with a significant connection to local water quality, making it attractive to funders for providing financial support.

The preserve also has a moderate amount of public and societal support including financial support that can help with conserving or managing this land into the future. However, the spruce swamp habitat does not have public access so it may not be valued as highly as other areas in the preserve that offer recreational opportunities such as hiking and guided nature walks (*2*). The likelihood of managing or alleviating climate impacts may be difficult due to dependence on water flow, low connectivity, and the relatively small geographic area of the spruce swamp habitat. These factors also impact the availability of nearby potential habitat refugia for spruce swamp species. While the interior of the preserve could act as a natural buffer/refuge for some species, not all species normally found in the spruce swamp habitat will likely survive in the forested non-wetland areas.

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

Red spruce is classified by the PNDI using the Climate Change Vulnerability Index developed by NatureServe as an S4 species, meaning it is identified as "extremely vulnerable and its range extent within Pennsylvania is likely to substantially decrease or disappear by 2050" (*3*).

According to the Northern Institute of Applied Climate Science's Climate Change Projections for Individual Tree Species, under both RCP 4.5 and 8.5 conditions species such as eastern hemlock, eastern white pine, pitch pine, yellow or swamp birch, red spruce, and serviceberry rank as having low adaptability, rare abundance, decreasing suitable habitat, and a poor capability to cope or persist with climate change (*37*). Blackgum was ranked as having high adaptability, good abundance, increasing suitable habitat, and a good capability of coping or persisting with climate change. While the suitable habitat for red maple is projected to decrease by 2100, the species' high adaptability and abundance increase its capability to cope with the impacts of climate change (*37*).

Table 1. Adaptability, abundance, habitat change, and capability of tree species in the Bear Creek spruce swamp habitat under RCP 4.5 and 8.5 conditions. *Source: NIACS Climate Change Projections for Individual Tree Species in Pennsylvania* (*37*).

			LOW CLIMATE CHANGE (RCP 4.5)		HIGH CLIMATE CHANGE (RCP 8.5)	
SPECIES	ADAPTABILITY	ABUNDANCE	HABITAT CHANGE	CAPABILITY	HABITAT CHANGE	CAPABILITY
Blackgum	+	○	▲	△	▲	△
Eastern hemlock	−	○	▼	▽	▼	▽
Eastern white pine	−	○	▼	▽	▼	▽
Pitch pine	○	○	▼	▽	▼	▽
Red maple	+	+	▼	△	▼	△
Red spruce	−	−	▼	▽	▼	▽
Serviceberry	○	−	▼	▽	▼	▽
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* (37)*.*

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: 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