Early-Successional Forests, Bear Creek Preserve

Climate Change Vulnerability Assessment for the Natural Lands Climate Adaptation Project

This document represents an evaluation of climate change vulnerability for early-successional forests 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

Early-successional forest occupies about 60 acres in the northwest portion of the Natural Lands' Bear Creek Preserve, which totals 3,565 acres. The early-successional forest was created through a prescribed burn effort that cleared 19.7 acres, together with mechanical thinning and herbicide applications to remove unwanted overstory tree species (e.g., maples) and invasive plants from an additional 26 acres (10.5 hectares) of land. The creation of this early-successional habitat was intended to promote diversity in forest age classes throughout the preserve, help maintain flora and fauna native to the area, and improve habitat quality for species such as the golden-winged warbler (*Vermivora chrysoptera)*, wood thrush (*Hylocichla mustelina)*, and ruffed grouse (*Bonasa umbellus*) (*1*).

Early-successional forests are typically short-lived, and are characterized by quick-growing and shade-intolerant species including small trees, shrubs, grasses, and other non-woody plants. Unless some degree of disturbance is maintained, these species are gradually replaced by shade-tolerant tree species that establish the forest overstory. Post-disturbance early-successional communities are also characterized by high productivity, nutrient flux, species diversity, and structural and spatial complexity (*2*). These are relatively defined communities and occur in xeric to moderately dry and acidic areas with thin or shallow soils (*3*).

The early-successional forest in the Bear Creek preserve is considered a dry oak–heath forest and is classified as an S4/S5 community by the Pennsylvania Natural Diversity Inventory (PNDI) of the Pennsylvania Natural Heritage Program (PNHP), meaning it is a relatively secure community that is considered widespread and abundant but there is some cause for concern about long-term decline (*4*). Oak species such as northern red oak (*Quercus rubra*), white oak (*Q. alba*), chestnut oak (*Q. prinus*) are highly desired species in the early-successional forest habitat in the Bear Creek preserve (*1*) due to their role as keystone species in the eastern United States (*5*). Other tree species often associated with this habitat type are red maple (*Acer rubrum*), sassafras (*Sassafras albidum*), black-gum (*Nyssa sylvatica*), and black/sweet birch (*Betula lento*). Eastern white pine (*Pinus strobus*), pitch pine (*P. rigida*), and American chestnut (*Castanea dentata*) occur occasionally. The shrub layer is variable, and can include black huckleberry (*Gaylussacia baccata*), low bush blueberry (*Vaccinium pallidum*), low sweet blueberry (*V. angustifolium*), highbush blueberry (*V. corymbosum)*, sheep laurel (*Kalmia angustifolia*), mountain laurel (*K. latifolia)*, scrub oak (*Q. ilicifolia),* and sweet fern (*Comptonia peregrina*). Common elements of the herbaceous layer include Canada mayflower (*Maianthemum canadense*), fly-poison (*Amianthium muscitoxicum)*, teaberry (*Gaultheria procumbens*), trailing arbutus (*Epigaea repens),* wild sarsaparilla (*Aralia nudicaulis*), bracken fern (*Pteridium aquilinum*), Pennsylvania sedge (*Carex pensylvanica*), and pink lady's slipper (*Cypripedium acaule*) (*3*, *4*, *6*).

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).

Early-successional forests are sensitive to changes in climate stressors such as air temperature, heat waves, precipitation amount/timing, timing of snowmelt/runoff, soil moisture, and drought, which have the potential to impact nutrient input, alter thermal regimes, promote invasive plants and pathogens, and allow establishment of undesirable overstory tree species that limit understory species diversity and habitat quality for early-successional fauna. Climate-driven changes in disturbance regimes (e.g., wildfires, extreme flooding, and storm events) also have the potential to alter species composition and habitat structure in early-successional forests. Early-successional forests in the region are also vulnerable to non-climate stressors such as invasive species and fire exclusion/suppression, which can impact species diversity and composition.

Species	Trend
Black/sweet birch (*Betula lento*)	▼
Blackgum *(Nyssa sylvatica)*	▲
Chestnut oak *(Quercus prinus)*	●
Eastern white pine *(Pinus strobus)*	▼
Northern red oak *(Quercus rubra)*	●
Pitch pine (*Pinus rigida*)	▼
Red maple *(Acer rubrum)*	▼ *Reduced climatic suitability but highly adaptable*
Sassafras *(Sassafras albidum)*	▲
White oak *(Quercus alba)*	▲

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

While early-successional forests are widely distributed across the region, their extent and continuity within Bear Creek Preserve is more limited. However, there is potential for this habitat to become more common through management or natural disturbance. Management actions that may help build the adaptive capacity of early-successional forests may include maintaining fire regimes to prevent succession and promoting restoration activities (including the removal of unwanted overstory trees).

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]
Air temperature	▲	• 6.1°F increase in average annual temperature in Luzerne County by 2050; 9.6°F increase by 2100 (*7*)
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*)
Precipitation	▲▼	• 5% increase in average annual precipitation (to 46.5 in) in Luzerne County by 2050; 12% increase (to 5.5 in) by 2100 (*8*) • 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*, *9*) • Likely increases in spring soil moisture and decreases in summer and fall soil moisture (*7*, *9*)
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*, *10*) • Overall trend toward earlier snowmelt in the year, largely due to warmer temperatures and increased rainfall (*7*)

- **Warmer air temperatures** and **more frequent and intense heat waves** are likely to lead to shifts in early-successional plant communities (*11*) by affecting soil health, nutrient availability, and fertility that then limit plant growth and primary production (*12–15*). The change in freeze patterns due to increased annual temperatures may reduce the reliability of spring growth cues and the patterns of leaf out (the timing of buds opening, which determines the availability of shelter and food for insects) (*16*, *17*). As temperatures rise, plant hardiness zones in the region will also shift. Together with increases in the frequency and severity of heat waves, this could impact species composition within the preserve, forcing some species out of their normal home range, changing the ecosystem structure and function, and possibly increasing the risk of invasion (*18–21*).
- **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. More frequent droughts (accompanied by hotter temperatures) will cause increased evapotranspiration, reduce water availability, and may result in less-frequent flooding during fall months (*7*). Although many component species within early-successional

[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.

forests are somewhat drought-tolerant (e.g., sassafras, scrub oak, pitch pine) declines in soil moisture could reduce successful seed establishment, resulting in regeneration failure (*22*). Vegetation in early-successional forests is also more exposed compared to areas at later stages of succession where the forest canopy has developed to a greater degree, which increases vulnerability to drought (particularly for new growth). Early-succession / young soils tend to have low porosity and are fairly compact, reducing their ability to hold water (*23*). During periods of drought when water availability is decreased, this can impact rooting depth/restrictions and nutrient availability for early successional species.

- **Reduced snowpack** and **earlier snowmelt** are likely to alter hydrology in early-successional forests. For instance, decreased snowpack could increasing soil freezing that impedes infiltration of water into the soil, increases runoff events, and leads to reductions in root biomass and stem respiration rates (*22*).

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*)

- **Climate-driven increases in wildfire activity** has the potential to help maintain dry oak–heath forests in early-successional stages, opening the tree canopy and promoting habitats that are diverse in species and structure (*2*). Increases in wildfire are likely to be most significant during dry years and periods of drought, when drying of the heath understory increase available fuel. Where wildfire leads to stump sprouting and releases natural regeneration, some management actions such as periodic tree harvesting and controlled burns may become less necessary for maintenance of early-successional habitats (*1*).
- **Increases in insect pests and diseases** are likely to alter forest structure and function (*18*) and can weaken ecosystem defenses to the impacts of climate stressors (*22*, *25*). Insects are physiologically and temperature sensitive, and projected temperature increases could increase their rate of development and allow more generations per year (*26*, *27*). In the Bear Creek preserve, pests such as forest tent caterpillars (*Malacosoma disstria*), hemlock woolly adelgid (*Adelges tsugae*), emerald ash borer (*Agrilus planipennis*), and the egg mass of a spongy moth *(Lymantria dispar)* have been detected. Additionally, beech bark disease and chestnut blight pathogens are also present. Since the forest is dominated by oak species, spongy moth infestations and oak wilt (caused by the fungal pathogen *Ceratocystis fagacearum*) are particular concerns for this habitat (*1*, *5*).
- **Increases in extreme flooding and storm events** will likely negatively impact dry oak–heath forests, which represent the early-successional forest type in Bear Creek Preserve. Dry oak–

heath forests are typically located on thin soils that have limited ability to absorb water during heavy rain events, which can result in excess runoff and flooding following heavy rain events. Increases in storms and associated flooding could also lead to increased soil erosion, loss of nutrients, and soil acidification (*12*). Understory species are particularly vulnerable to flooding, and mortality can occur due to windthrow of canopy trees. Where prolonged flooding saturates soils, seed establishment among species adapted to drier soils (e.g., oaks) is likely to be reduced, while those that can tolerate longer periods of inundation may increase; conditions may also become more favorable for invasive plants (*1*). Extreme flooding also has the potential to reduce water quality where increased runoff and contaminants enter the habitat from nearby roads (*16*).

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, habitat connectivity, and the ability for understory species to establish and regenerate.

- **Invasive and problematic species** can alter the abundance and diversity of native species through competition for resources, increased predation risk, and/or disease spread (*28*). For example, problematic species such as the hay-scented fern (*Dennstaedtia punctilobula*) (which has a wide climatic tolerance, low desirability to insects, and high fire tolerance) can compete with tree seedlings in this habitat, jeopardizing species regeneration and the overall composition of species able to grow in the early-successional forest (*1*, *29*, *30*). 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, they could become more problematic as temperatures rise and more invasive species are able to move north into Pennsylvania's southeastern forests (*1*). Recent studies have shown that some younger forests in southeastern PA were more abundant in invasive plants than older forests and future understory invasion may be a threat for these habitats (*31*).
- **Fire exclusion/suppression** is a threat to disturbance-dependent species that make up the open forest understory, as many of these primarily regenerate following frequent, low-intensity fires (e.g., scrub oak) (*32*, *33*). Prescribed burns can be used to restore historic fire regimes, encouraging the regeneration of canopy oaks and fire-tolerant species and helping to establish diverse forest age classes and biodiversity (*1*).

Adaptive Capacity

High 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

Although dry oak forests are widespread within Bear Creek Preserve, the extent and continuity of early-successional habitat is lower. However, there is potential for this habitat to increase in area through management or natural disturbance, and both deer herbivory and invasive species pressure is lower in the Bear Creek Preserve compared to surrounding areas. Land-use conversion could be a threat for unprotected lands in the region, but the surrounding landscape is highly permeable and the preserve is mostly contiguous, with large protected lands bordering it (e.g., state forest, Pennsylvania game lands, Army Corp of Engineers protected areas, and properties that hold conservation easements). The large landscape of protected forest creates an opportunity for species migration and builds in resilience from disturbance within smaller portions of the landscape. While the preserve has two gas pipelines, a few roads, a trail network, few invasive plants, and Francis E. Walter Dam these factors are not yet large scale enough to alter the permeability or integrity of the habitat (*1*).

Habitat diversity

Early-successional forests within Bear Creek Preserve are dominated by oaks, ericaceous shrubs, and woody vines, ranging in elevation approximately 1,400–1,950 ft (*1*). They are located on hilly, topographically-complex topography that characterizes Bear Creek Preserve, which hosts a variety of landforms including wide dissected plateaus, intermountain basins, and deep valleys (*34*). The Preserve also has three major streams (Bear Creek, Shades Creek, and Stony Run) and the Lehigh River, which have contributed to the development of valleys with steep walls. The area is underlain by three geologic formations consisting of varying mixtures of sandstones, siltstones, claystones, conglomerates, mudstones, and shales, all of which provide relatively good groundwater storage (*34*). Overall, the topographic and substrate diversity present within the larger Preserve together with the relatively diverse species composition and habitat structure of restored early-successional forests are likely to result in greater resilience to future climate changes (*35–37*).

Resistance and recovery

The early-successional forest in Bear Creek Preserve is likely to benefit from climate-driven increases in disturbances, which reset succession, and oak species are able to recover rapidly from disturbances through stump sprouting and seedlings. Additionally, lower levels of deer grazing in the area means that new seedlings are more likely to survive to maturity, replacing trees that may be damaged or lost during disturbances (*1*). Carbon fertilization as a result of increased atmospheric carbon dioxide also has the potential to increase growth rates. However, studies suggest that rapid growth as a result of carbon fertilization is also tied to shortened tree lifespans, resulting in little long-term gain (*38*). Dramatic declines in some species due to insects or disease, or more widespread degradation due to invasive species or deer could also lead to more widespread declines in this habitat type, particularly in combination with increases in temperature and precipitation that stress existing vegetation (*1*).

Management potential

There is general support of the Bear Creek preserve and the recreational activities available in its forested areas (i.e., birding and hiking). The preserve is a frequented area for colleges, high schools, and grade schools for various field work and guided nature hikes. In addition to its recreational value, the preserve is also a habitat for migratory songbirds and the proposed management of this forest as early-successional habitat (i.e., through rotational cutting) is supported by numerous public agencies (i.e., Pennsylvania Department of Environmental Protection, Pennsylvania Department of Conservation and Natural Resources) and private organizations (Audubon Pennsylvania, Cornell Lab of Ornithology). The preserve also has a moderate amount of financial support that can help with conserving and managing the land into the future. This particular habitat is already being well managed to control existing stressors and it is likely that future impacts to the early successional forest habitat may be within the capacity of the staff and outside consultants to manage (*1*).

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 the Bear Creek preserve's early-successional forest habitat under RCP 4.5 and 8.5 conditions. *Source: NIACS Climate Change Projections for Individual Tree Species in Pennsylvania* (*39*).

			LOW CLIMATE CHANGE (RCP 4.5)		HIGH CLIMATE CHANGE (RCP 8.5)	
SPECIES	ADAPTABILITY	ABUNDANCE	HABITAT CHANGE	CAPABILITY	HABITAT CHANGE	CAPABILITY
Black/sweet birch	–	+	▼	▽	▼	▽
Blackgum	+	○	▲	△	▲	△
Chestnut oak	+	+	●	△	●	△
Eastern white pine	–	○	▼	▽	▼	▽
Northern red oak	+	+	●	△	●	△
Pitch pine	○	○	▼	▽	▼	▽
Red maple	+	+	▼	△	▼	△
Sassafras	○	○	▲	△	▲	△
White oak	+	○	▲	△	▲	△

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* (*39*).

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
●	**No change**		