Identifying Species in Pennsylvania Potentially Vulnerable to Climate Change

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Pennsylvania Natural Heritage Program

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ON THE COVER:
Left: Wood turtle (*Glyptemys insculpta*)-photo by Charlie Eichelberger, Center: Creeping snowberry (*Gaultheria hispidula*)-photo by Charlie Eichelberger, Right: Bog copper (*Lycaena epixanthe*)-photo by Betsy Leppo

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Executive Summary

Climate change will likely impact the distribution and abundance of plant and animal species in Pennsylvania. Those species vulnerable to climate may experience a shift in their ranges within the state. Recognizing climate change vulnerability is an important first step in preparing for future conservation efforts. However, no assessments have yet been conducted to determine which Pennsylvania species are vulnerable to climate change. The goals of this project were to 1) compile a priority list of species occurring in Pennsylvania that are likely vulnerable to climate change and 2) examine the climate change vulnerability of species included in the priority list. The overall objective was to not only identify climate change vulnerable species but to also examine the abiotic factors and life history characteristics that contribute to their increased vulnerability.

A priority list of species for climate change assessment was compiled based on those species contained in Pennsylvania's State Wildlife Action Plan (WAP), species' distribution, potential vulnerable habitat types, and expert opinion. In total, the list contained 525 species. Climate change vulnerability assessments were completed for 85 of the species using the Climate Change Vulnerability Index (CCVI v2.0) developed by NatureServe. The CCVI allows the user to examine the exposure and sensitivity of a species to a series of risk factors associated with climate change. An examination of vulnerability patterns among taxonomic groups indicated that amphibians and mussels were the most vulnerable groups. Insects, plants, and reptiles exhibited a wider range of variability to climate change vulnerability, while birds and cave invertebrates appeared to be less vulnerable to short-term climate change effects. A more in depth discussion of the results of each taxonomic group was presented along with a breakdown of the CCVI score and individual risk factors for each species. A summary of the findings was compiled for each species. In addition, general risk factors contributing to overall species vulnerability were discussed along with a few caveats associated with the interpretation of the CCVI results.

Introduction

Climate change will likely alter the distribution and abundance of plant and animal species in Pennsylvania. However, the response to climate change will likely vary among species. Mobile species that are not restricted by habitat constraints and geographic or anthropogenic barriers may shift their ranges northward in response to climate change. Northern edge-of-range species that fall into this category may actually shift their ranges beyond Pennsylvania's borders while being replaced by species that were once more southerly distributed. Pennsylvania may even gain new species from surrounding states as ranges shift.

On the other hand, some species may have very little ability to move in response to climate change due to various limitations/obstacles. These species may likely experience a reduction in range or abundance. Other species may likely remain stable within their current range or may even expand their existing range. This potential shift in species occurrences and ranges will create challenges for those agencies responsible for their conservation and management. The first step in addressing these challenges is to determine which species are most vulnerable to climate change and what factors lend towards their vulnerability.

The goal of this project was two-fold. First, compile a priority list of species occurring in Pennsylvania that are likely vulnerable to climate change. Second, using the Climate Change Vulnerability Index (CCVI), an assessment tool developed by NatureServe, examine the vulnerability of species included in the priority species list. The goal was to not only identify climate change vulnerable species but to also examine the abiotic factors and life history characteristics that contribute to their increased vulnerability.

Methods

Development of a Priority Assessment List

With over 21,000 species of organisms in Pennsylvania (includes invertebrates, plants and algae, fungi and lichens, and vertebrates) (www.aa.psu.edu/pabs/invertebrates.htm), it was necessary to develop a more refined list of priority species for climate change vulnerability assessment. Existing lists of species of conservation concern, a review of species ranges in Pennsylvania, and suggestions from experts were considered when developing a shorter priority vulnerability assessment list.

Examination of Species Vulnerability to Climate Change

Vulnerability to climate change was assessed by considering the two main components of vulnerability as defined by Williams et al. (2008): the exposure of a species to climate change within a defined area combined with the sensitivity of a species to climate change. NatureServe's recently developed Climate Change Vulnerability Index (CCVI) provides this capability in a rapid, scientifically defensible assessment of species' vulnerability to climate change (Young et al. 2010). The CCVI contemplates vulnerability to climate change by the year 2050, a typical cut-off date for predictions made in the International Panel on Climate Change reports (e.g., IPCC 2007). The index is designed to complement NatureServe's conservation ranks (such as G-ranks and S-ranks) (Master et al. 2000) and does not duplicate factors considered in the other conservation ranks such as population size, range size, and demographic factors. Conservation ranks should therefore be used in concert with vulnerability ranks to aid in the interpretation of results.

The index was developed on an Excel platform which allows the user to enter categorical, weighted responses (risk factor scores) to a series of questions about risk factors related to a species exposure and sensitivity to climate change. The risk factors considered may be divided into general categories including direct exposure, indirect exposure, sensitivity, documented responses, and modeled responses; and are briefly described below (Young et al. 2010; Byers and Norris 2011). The complete CCVI v2.0 tool and supporting guidance and documentation are available on NatureServe's website at the following link: http://www.natureserve.org/prodServices/climatechange/ccvi.jsp.

Exposure

Direct

- Temperature change: predicted change in annual temperature by 2050, calculated over the range of the species in Pennsylvania.
- Moisture change: predicted net change in moisture based on the Hamon AET:PET Moisture Metric, calculated over the range of the species in Pennsylvania.

Indirect

- Exposure to sea level rise: Potential impact on a small portion of Pennsylvania.
- Distribution relative to natural and anthropogenic barriers: Natural barriers may exist within or beyond a species geographic range that would inhibit movement into new areas in response to climate change. Similarly, anthropogenic barriers may exist that could also restrict dispersal.
- Predicted impact of land use changes resulting form human responses to climate change: Strategies to mitigate climate change effects such as wind farms and biofuel production may impact species that use these areas.

Sensitivity

- Dispersal and movements: The ability of a species to move or shift locations in response to climate change.
- Predicted sensitivity to temperature and moisture changes: Refers to the environmental requirements/tolerances of a species.
    - Predicted sensitivity to changes in temperature.

        - Historical thermal niche: exposure to past variations in temperature.
        - Current physiologic thermal niche.
    - Predicted sensitivity to changes in precipitation, hydrology, or moisture regime.
        - Historical hydrological niche: exposure to past variations in precipitation.
        - Current physiologic hydrologic niche.
    - Dependence on a specific disturbance regime likely to be impacted by climate change: Changes in disturbance regimes (e.g., frequency and intensity) due to climate change may impact the species that depend on these events.
    - Dependence on ice, ice-edge, or snow-cover habitats: This factor may be of minor significance depending on a species range in Pennsylvania.
- Restriction to uncommon geological features or derivates: This factor pertains to a species requirement for a specific substrate, soils, or physical feature (e.g., cave, talus slope, limestone outcrops) that may make movement in response to climate change difficult due to the uncommonness of the geological feature.
- Reliance on interspecific interactions: Species that depend on other species may be more vulnerable to climate change.
    - Dependence on other species to generate habitat.
    - Dietary versatility (animals only).
    - Pollinator versatility (plants only).
    - Dependence on other species for propagule dispersal.
    - Forms part of an interspecific interaction not covered above.
- Genetic factors: A species' ability to adapt to changing environmental conditions is largely a function of its existing genetic variation.
    - Measured genetic variation.
    - Occurrence of bottlenecks in recent evolutionary history.
- Phenological response to changing seasonal temperature and precipitation dynamics: Recent research suggests that some phylogenetic groups are declining due to lack of response to annual temperature dynamics, including some bird species that have not advanced their migration times, and some temperate zone plants that are not adjusting their flowering times.

<u>Documented or Modeled Responses to Climate Change</u> (optional, if available)

- Documented responses to recent climate change: The results of research may be available that document changes within species that can be definitively linked to climate change.
- Modeled future change in range or population size: The results of models may be available that demonstrate changes in a species' range or population size due to climate change.
- Overlap of modeled future range with current range: The results of future distribution models can be compared to current range maps to address potential overlap.

- Occurrences of protected areas in modeled future distribution: The results of future distribution models can be compared to present protected areas to address potential overlap.

Several steps were completed prior to using the CCVI. First, the assessment area was defined. This project focused on species whose ranges encompass all or a portion of Pennsylvania. Pennsylvania natural heritage species occurrence data and other sources of species range information, such as maps from the 2nd Annual Breeding Bird Atlas (http://www.bird.atlasing.org/Atlas/PA/) and plant distribution maps from Rhoads and Klein (1993), were used to develop an idea of a species range within Pennsylvania. Second, life history information was collected for each species from various sources including natural heritage data, NatureServe's Explorer database, peer-reviewed and white paper literature, and consultation with experts. Third, downscaled climate predictions about temperature and moisture (to answer direct exposure questions) were downloaded in a GIS format from Climate Wizard (Girvetz et al. 2009) (http://climatewizard.org) based on instructions provided in the associated guidelines for CCVI usage.

Once all supporting information was assembled, the CCVI spreadsheet was completed and a vulnerability rank and confidence interval was generated for each species (see Appendix 2 for definitions of risk factor scores and vulnerability index scores). The overall vulnerability score and individual risk factors were examined to isolate those factors that contribute most and least to the vulnerability of a species (as presented in Appendices 4 and 5). This information was used to compile vulnerability summary sheets for each species.

Results

Priority Species Assessment List

A priority list of species that would serve as good candidates for climate change vulnerability assessments was compiled. In total, 525 species were included in the list, 15 amphibians, 41 birds, 55 fish, 102 invertebrates, 19 mammals, 22 mussels, 253 plants, and 18 reptiles (see Appendix 1). Although this list is rather large, it represents only a small fraction of all species found in Pennsylvania (if algae, fungi, and lichens are included) and can be revised for future work dependent on the focus.

Most of the animals in the list are also included in Pennsylvania's State Wildlife Action Plan (WAP). Since Pennsylvania's WAP is currently undergoing an update to address climate change, information about species vulnerability to climate change may aid in this task. Other species were added based on their distribution within Pennsylvania. We felt it was important to examine edge of range species in Pennsylvania, regardless of their conservation status, since these species may likely experience more dramatic range changes due to climate change (either an increase in range within the state for southern affiliates or a shrinking range within Pennsylvania for northern affiliate species).

Like the animal list, edge-of-range plants were included in the priority list along with some species identified as most critically imperiled in Pennsylvania. Also included were plants found in habitats that are likely vulnerable to climate change effects such as isolated, high elevation wetlands. Many of the plants included in the list are of conservation concern in Pennsylvania.

Species Vulnerability to Climate Change

Vulnerability assessments were conducted for 85 species whose ranges include portions of Pennsylvania or the entire state. The original assessments were completed in the CCVI v1.0, but upon improvements to the index, all species were reanalyzed using CCVI v2.0. The vulnerability ranks by taxonomic group are shown in Figure 1 (see also Appendix 2 for vulnerability rank definitions). Care must be taken when interpreting the patterns of these results. Only a small number of species was sampled within each taxonomic group so that the patterns seen in Figure 1 may not be representative of entire taxonomic groups found in Pennsylvania. Additional species must be assessed within taxonomic groups before more definitive conclusions can be drawn about the vulnerability of specific groups. However, some patterns seen in this vulnerability assessment are similar to trends noted by others using the CCVI (Young et al. 2010; Byers and Norris 2011).

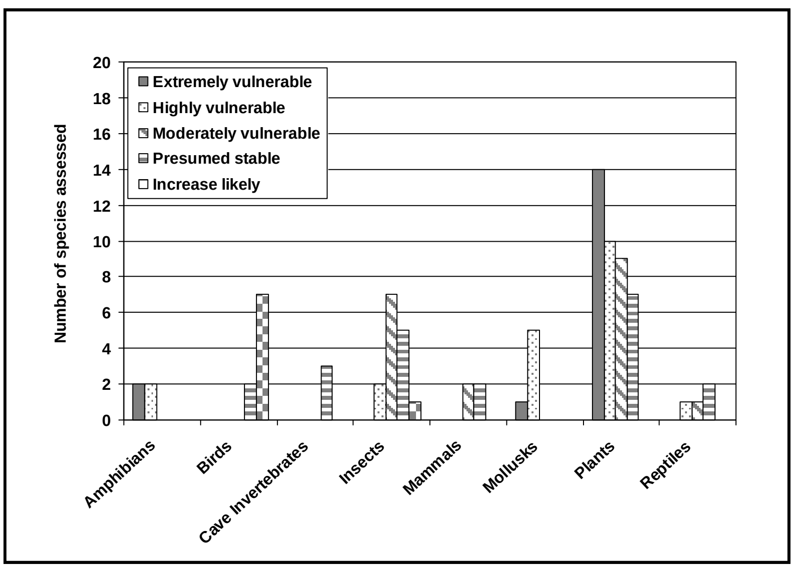

Figure 1. Results of climate change vulnerability analyses by taxonomic group.

Based on our CCVI results, some taxonomic groups appear to be more vulnerable to climate change than others (Figure 1; Appendix 3). All of the amphibians (n=4) and mussels (n=6) were scored as either extremely vulnerable or highly vulnerable to climate change. For these species, the CCVI suggests that the abundance and/or range of these species within Pennsylvania will likely decrease significantly or disappear entirely from the state by 2050. Other taxonomic groups (i.e., insects, plants, and reptiles) exhibit a wider range of variability to climate change vulnerability. For example, 60% of the plants evaluated are either extremely vulnerable or highly vulnerable, whereas, 22% are moderately vulnerable and 18% are considered stable. Two groups, birds and cave invertebrates, appear to be less vulnerable to short-term climate change effects. As a group, birds share common characteristics that help to potentially lessen the effects of climate change. For the cave invertebrates, observations that many obligate cave species persisted in situ through recent glaciations suggest that caves and groundwater-fed aquatic systems are well buffered from aboveground climate (Culver et al. 2003; Hamilton-Smith and Finlayson 2003; Lamareux 2004; Young et al. 2009).

A more in depth discussion of the results for each taxonomic group is presented in the sections to follow. The CCVI results for each species along with individual risk factor scores are presented in Appendices 3-5. A summary of each species climate change vulnerability assessment is presented in Appendix 6.

Amphibians

Figure 2. Spadefoot toad (*Scaphiopus holbrookii*), photo by Charlie Eichelberger.

Four amphibians from Pennsylvania's WAP were evaluated and have risk factors in common that contribute to their extremely or highly vulnerable index scores. The main CCVI risk factors contributing to vulnerability include: the presence of natural and anthropogenic barriers that limit a species' ability to move beyond its current range in Pennsylvania, inability to move long distances to colonize new sites, and dependence on cooler microsites and moisture regimes that will likely be altered by climate change. Eastern hellbenders (*Cryptobranchus alleganiensis*) and Jefferson salamanders (*Ambystoma jeffersonianum*) also require specific physical habitat features (i.e., stream bottoms with boulders and large, flat rocks and vernal pools with pHs within a specific range) and have restricted diets that add to their likely vulnerability to climate change.

Scientific Name	**Common Name**	**Global Rank**	**State Rank**	**Index Score**
Cryptobranchus alleganiensis	Eastern hellbender	G3G4	S3	Extremely vulnerable
Scaphiopus holbrookii	Spadefoot toad	G5	S1	Extremely vulnerable
Ambystoma jeffersonianum	Jefferson salamander	G4	S4	Highly vulnerable
Pseudacris brachyphona	Mountain chorus frog	G5	S1	Highly vulnerable

Similar to our results, other investigators also recognize that climate change is a potential problem for amphibian populations (Ovaska 1997; Donnelly and Crump 1998; Alford and Richards 1999; Alexander and Eischedi 2001; Carey and Alexander 2003; Blaustein et al. 2010). In their review, Blaustein et al. (2010) reported that multiple factors related to climate change, including those identified by the CCVI for these four amphibian species, may affect survival, growth, reproduction, and dispersal capabilities of amphibians along with habitat quality and more complex interactions.

Birds

The vulnerabilities of nine WAP birds were considered. Overall, the CCVI results suggest that these birds are less vulnerable to short-term climate change effects and many may actually increase their abundance/range in Pennsylvania. These results are not surprising given that the birds examined are able to disperse over long distances, move over or around natural and anthropogenic obstacles, and tend to have less habitat specificity in terms of geologic features, temperature and hydrologic regime.

Figure 3. Tundra swan (*Cygnus columbianus*), photo by Charlie Eichelberger.

Scientific Name	**Common Name**	**Global Rank**	**State Rank**	**Index Score**
Dendroica cerulean	Cerulean warbler	G4	S4	Presumed stable
Helmitheros vermivorus	Worm-eating warbler	G5	S4	Presumed stable
Vermivora chrysoptera	Golden-winged warbler	G4	S4	Increase likely
Ammodramus henslowii	Henslow's sparrow	G4	S4	Increase likely
Cygnus columbianus	Tundra swan	G5	S3	Increase likely
Vermivora pinus	Blue-winged warbler	G5	S4	Increase likely
Hylocichla mustelina	Wood thrush	G5	S5	Increase likely
Paranga olivacea	Scarlet tanager	G5	S5	Increase likely
Seiurus motacilla	Louisiana waterthrush	G5	S5	Increase likely

Recent bird survey analyses help support the idea that many of the birds included in this project may actually increase in abundance/range in Pennsylvania by 2050. Audubon (2009) reported that almost all of the birds in North America are moving northward and inland in response to changing environmental conditions. Pennsylvania is not the edge-of-range for any of the birds examined. As bird ranges shift northward in response to climate change, it is likely that some birds in Pennsylvania will increase their abundance/range within the state given that suitable habitat is available. However, it is important to remember that vulnerability ranks are based on the vulnerability of a species within a defined assessment area. For migratory species, such as the ones examined within this taxonomic group, the CCVI only evaluates climate change vulnerability within the assessment area and not over the entire range. Conditions may differ throughout a species range that could ultimately affect population dynamics and is not accounted for in the CCVI results, but should be considered when planning management and conservation efforts.

Cave Invertebrates

Based on our sample, the cave invertebrates represent another taxonomic group that is likely to remain unchanged by short-term climate change effects in Pennsylvania. Cave invertebrates are sensitive to groundwater contamination and groundwater drawdown (Dickson et al. 1979; Danielopol 1981; Malard et al. 1996; Culver et al. 2000) but are likely buffered from projected climate change effects due to the climate stability of cave interiors (Poulson and White 1969). The CCVI also automatically gives obligate cave and groundwater species a higher resistance rating to climate change impacts based on evidence that many obligate cave species persisted in situ during widespread periods of climate change during the Pleistocene era (Culver et al. 2003; Lamoreux 2004).

Scientific Name	Common Name	Global Rank	State Rank	Index Score
Stygobromus stellmacki	Stellmack's Cave amphipod	G1G2	S1	Presumed stable
Sphalloplana pricei	Refton Cave planarian	G2G3	S1	Presumed stable
Caecidotea kenki	an isopod	G3	S1	Presumed stable

Invertebrates - Insects

Figure 4. Frosted elfin (*Callophyrus irus*), photo by Monica Miller.

Several butterflies, moths, dragonflies, and beetles were evaluated. The species that appear more vulnerable to climate change generally have several risk factors in common that contribute most to their vulnerability. For the butterflies and moths, those risk factors include: an association with cooler environments, dependence on only a few host plants, and sensitivity to changes in soil moisture and/or hydrological regime. On the other hand, the ability to disperse longer distances to new sites, lack of habitat specialization, and positive responses to disturbance were factors that contributed a higher resistance to climate change for the other moths and butterflies.

Scientific Name	Common Name	Global Rank	State Rank	Index Score
Pieris virginiensis	West Virginia white	G3?	S2S3	Highly vulnerable
Lycaena epixanthe	Bog copper	G4G5	S2	Highly vulnerable
Pyrgus wyandot	Appalachian grizzled skipper	G1G2Q	S1	Moderately vulnerable
Cicindela marginipennis	Cobblestone tiger beetle	G2	S1	Moderately vulnerable
Cicindela ancocisconensis	Appalachian tiger beetle	G3	S1	Moderately vulnerable
Gomphus viridifrons	Green-faced clubtail	G3G4	S1	Moderately vulnerable
Gomphus quadricolor	Rapids clubtail	G3G4	S1S2	Moderately vulnerable
Papaipema sp. 1	Flypoison borer moth	G2G3	S2	Moderately vulnerable

Scientific Name	Common Name	Global Rank	State Rank	Index Score
Calephelis borealis	Northern metalmark	G3G4	S2	Moderately vulnerable
Speyeria idalia	Regal fritillary	G3	S1	Presumed stable
Zale curema	Northeastern pine zale	G3G4	S1	Presumed stable
Callophrys irus	Frosted elfin	G3	S1S2	Presumed stable
Cicindela patruela	Northen barrens tiger beetle	G3	S2S3	Presumed stable
Lemmeria digitalis	Fingered lemmeria moth	G4	S2S4	Presumed stable
Calycopis cecrops	Red-banded hairstreak	G5	S4	Increase likely

For the dragonflies (green-faced clubtail (*Gomphus viridifrons*)and rapids clubtail (*G. quadricolor*)), the risk factors that contributed most to climate change vulnerability were an association with cooler environments and sensitivity to changes in stream hydrological regimes (both historically and predicted). However, one mitigating factor may be that these dragonflies are able to disperse longer distances to new, uncolonized sites.

The cobblestone tiger beetle (*Cicindela marginipennis*) and the Appalachian tiger beetle (*Pyrgus wyandot*) both appear to be moderately vulnerable to climate change due mostly to their habitat specificity, negative consequences as a result of increased flooding events, and evidence of genetic bottlenecks. The northern barrens tiger beetle (*Cicindela patruela*) has some similar risk factors compared to the other beetles but is less sensitive to disturbance and there is no documented evidence of genetic bottlenecks. Like the other insects included in this assessment, all of the beetles are capable of dispersing longer distances if suitable habitat is available.

Mammals

The climate change vulnerabilities of four mammals from Pennsylvania's WAP were assessed. Both the eastern small-footed bat (*Myotis leibii*) and the Allegheny woodrat (*Neotoma magister*) are habitat specialists, a risk factor that contributes to their moderate vulnerability score. In addition, the eastern small-footed bat may be negatively impacted by wind farm development and use, requires cooler microenvironments within caves, and has experienced less than average precipitation variation within its Pennsylvania range. The Allegheny woodrat typically does not disperse long distances and is restricted in its movement beyond its current range due to natural and anthropogenic barriers.

Figure 5. Allegheny woodrat (*Neotoma magister*), photo by Charlie Eichelberger.

Scientific Name	Common Name	Global Rank	State Rank	Index Score
Myotis leibii	Eastern small-footed bat	G3	S1B, S1N	Moderately vulnerable
Neotoma magister	Allegheny woodrat	G3G4	S3	Moderately vulnerable
Sylvilagus obscurus	Appalachian cottontail	G4	SU	Presumed stable
Lepus americanus	Snowshoe hare	G5	S3S4	Presumed stable

The CCVI considers both the Appalachian cottontail (*Sylvilagus obscures*) and the snowshoe hare (*Lepus americanus*) as stable within the short-term due mostly to their ability to disperse long distances and low dependence on processes likely to be altered by climate change. Snowshoe hare results from the CCVI also noted that although the species is scored as presumed stable, evidence suggests that the species range may shift outside of Pennsylvania.

Mollusks

Figure 6. Yellow lampmussel (*Lampsilis cariosa*), photo by Beth Meyer.

Based on our sample, the mollusks represent one taxonomic group in Pennsylvania that is likely to be negatively affected by climate change. All of the mussels below share similar risk factors that contribute to their heightened vulnerability. These risk factors include: inability to disperse well beyond their current range due to anthropogenic barriers (i.e., dams), water quality issues associated with climate change mitigation activities, poor dispersal mechanisms, negative affects of increased flooding due to change in precipitation patterns, and the fact that all of the mussels depend on a few fish species to serve as glochidial hosts. Furthermore, the eastern pearlshell (*Margaritifera margaritifera*) is limited to cold water trout streams that will likely experience water temperature increases due to climate change.

Scientific Name	Common Name	Global Rank	State Rank	Index Score
Margaritifera margaritifera	Eastern pearlshell	G4	G4	Extremely vulnerable
Alasmidonta heterdon	Dwarf wedgemussel	G1G2	G1G2	Highly vulnerable
Pleurobema clava	Clubshell	G2	G2	Highly vulnerable
Villosa fabalis	Rayed bean	G2	G2	Highly vulnerable
Epioblasma torulosa rangiana	Northern riffleshell	G2	G2	Highly vulnerable
Lampsilis cariosa	Yellow lampmussel	G3G4	G3G4	Highly vulnerable

Plants

Figure 7. Bog-rosemary (*Andromeda polifolia*), photo by Denise Watts.

Forty plants were included in this climate change vulnerability assessment and range from extremely vulnerable to presumed stable. Vulnerability to climate change is due to a combination of multiple risk factors. The most common risk factors were: natural barriers exist that could inhibit northward migration, limited dispersal capabilities, restricted to cooler environments found at higher elevations and along the northern tier of Pennsylvania, dependence on a specific hydrological or moisture regime (i.e., wetland obligate plants), and dependence on other species (i.e., requires mycorrhizal associations). The white-fringed orchid (*Platanthera blephariglottis*) and willow oak, (*Quercus phellos*) are also restricted to uncommon geologic features such as mesic calcareous forests and wet, sandy coastal soils. The vulnerability of the white trout-lily (*Erythornium albidum*) is increased by its dependence on ants to aid in seed dispersal.

Plants with presumed stable scores are generally more habitat generalists, able to disperse longer distances, and are less dependent on cooler temperatures and hydrological conditions.

Scientific Name	**Common Name**	**Global Rank**	**State Rank**	**Index Score**
Platanthera blephariglottis	White fringed-orchid	G4G5	S2S3	Extremely vulnerable
Oclemena nemoralis	Leafy bog aster	G5	S1	Extremely vulnerable
Scheuchzeria palustris	Pod-grass	G5	S1	Extremely vulnerable
Carex oligosperma	Few-seeded sedge	G5	S2	Extremely vulnerable
Muhlenbergia uniflora	Fall dropseed muhly	G5	S2	Extremely vulnerable
Utricularia cornuta	Horned bladderwort	G5	S2	Extremely vulnerable
Carex limosa	Mud sedge	G5	S2	Extremely vulnerable
Andromeda polifolia)	Bog-rosemary	G5	S3	Extremely vulnerable
Gaultheria hispidula	Creeping snowberry	G5	S3	Extremely vulnerable
Rhododendron groenlandicum	Labrador-tea	G5	S3	Extremely vulnerable
Abies balsamea	Balsam fir	G5	S3	Extremely vulnerable
Picea rubens	Red spruce	G5	S4	Extremely vulnerable
Kalmia polifolia	Bog laurel	G5	S4/S5	Extremely vulnerable
Dalibarda repens	Dewdrop	G5	SNR	Extremely vulnerable
Vaccinium macrocarpon	Cranberry	G4	SNR	Highly vulnerable
Tipularia discolor	Cranefly orchid	G4G5	S3	Highly vulnerable
Arceuthobium pusillum	Dwarf mistletoe	G5	S2	Highly vulnerable
Carex paupercula	Bog sedge	G5	S3	Highly vulnerable
Maianthemum trifolium	False Solomon's-seal	G5	S4	Highly vulnerable
Rhododendron canadense	Rhodora	G5	SNR	Highly vulnerable
Coptis trifolia	Goldthread	G5	SNR	Highly vulnerable
Vaccinium oxycossos	Small cranberry	G5	SNR	Highly vulnerable

Scientific Name	Common Name	Global Rank	State Rank	Index Score
Picea mariana	Black spruce	G5	SNR	Highly vulnerable
Viola selkirkii	Great spurred violet	G5?	S3	Highly vulnerable
Ruellia strepens	Wild limestone petunia	G4G5	S2	Moderately vulnerable
Schoenoplectus subterminalis	Water bulrush	G4G5	S3	Moderately vulnerable
Quercus phellos	Willow oak	G5	S2	Moderately vulnerable
Bartonia paniculata	Screwstem	G5	S3	Moderately vulnerable
Juncus filiformis	Thread rush	G5	S3	Moderately vulnerable
Erythornium albidum	White trout-lily	G5	S3	Moderately vulnerable
Chamaedaphne calyculata	Leatherleaf	G5	SNR	Moderately vulnerable
Cornus canadensis	Bunchberry	G5	SNR	Moderately vulnerable
Rhynchospora alba	White beak-rush	G5	SNR	Moderately vulnerable
Solidago uliginosa	Bog goldenrod	G4G5	S3	Presumed stable
Conoclinum coelestinum	Mistflower	G5	S3	Presumed stable
Galium latifolium	Purple bedstraw	G5	S3	Presumed stable
Rotala ramosior	Toothcup	G5	S3	Presumed stable
Salix petiolaris	Meadow willow	G5	S4	Presumed stable
Eriophorum virginicum	Tawny cotton-grass	G5	SNR	Presumed stable
Prunus pumila var. depressa	Eastern sand cherry	G5T5	S1	Presumed stable

Reptiles

Figure 8. Bog turtle (*Glyptemys muhlenbergii*), photo by Charlie Eichelberger.

The climate change vulnerabilities of four of Pennsylvania's WAP reptiles were evaluated. The bog turtle (*Glyptemys muhlenbergii*) and spotted turtle (*Clemmys guttata*) had two similar risk factors that contributed to their increased vulnerability to climate change, limited to only short distance dispersal and the presence of anthropogenic barriers that could potentially block movement to new sites. Bog turtles also have very specific habitat requirements that add to their increased vulnerability. The timber rattlesnake (*Crotalus horridus*) and wood turtle (*Glyptemys insculpta*) were both scored as presumed stable due to such factors as the ability to move longer distances to new sites and dietary versatility.

Scientific Name	Common Name	Global Rank	State Rank	Index Score
Glyptemys muhlenbergii	Bog turtle	G3	S2	Highly vulnerable
Clemmys guttata	Spotted turtle	G5	S3	Moderately vulnerable
Crotalus horridus	Timber rattlesnake	G4	S3S4	Presumed stable
Glyptemys insculpta	Wood turtle	G4	S3S4	Presumed stable

Discussion

During the course of the project, climate change vulnerability assessments were conducted for 85 species whose ranges include portions of Pennsylvania or the entire state. The results of these assessments provide us with some insight into risk factors (for the species assessed in this project) that contribute to climate change vulnerability and can be divided into two general categories, limited dispersal capability and specialized habitat requirements.

Limited Dispersal Capability

'Limited dispersal capability' was addressed in four of the risk factors (natural barriers to movement, anthropogenic barriers to movement, physical ability to move to a new site, and dependence on other species for propagule dispersal). The ability of many of the species to move beyond their current ranges is limited by natural barriers such as extensive forest blocks surrounding isolated wetlands that would limit the movement of wetland plants. Anthropogenic barriers, such as dams, large highways, and agricultural areas, also form potential obstacles for range expansion.

In addition to physical barriers impacting range expansion, the ability to actually disperse long distances is limited for many species. Some of the plants and all of the mussels assessed share this limitation. For the plants, lack of specialized structures for dispersal by wind or attractive coloration for animal dispersal limits long distance dispersal potential. For the mussels, as adults, many are mostly non-migratory with only limited vertical movement and possibly passive movement due to flood events (NYNHP 2010). On the other hand, birds and some of the flying insects will likely be able to move beyond their current range given their ability to fly long distances and maneuver around or over natural and anthropogenic obstacles.

Dependence on other species for movement is another likely risk factor associated with limited dispersal capability. Some species included in this project may be more vulnerable to climate change due to their dependence on other species for propagule dispersal. All of the mussels examined require a few fish species to serve as glochidial hosts (Spoo 2008). White trout-lilies are adapted for ant dispersal of seeds (Thompson 1981).

Specialized Habitat Requirements

'Specialized habitat requirements' was the second general category of risk factors commonly associated with increased vulnerability to climate change. Three risk factors dealt with habitat requirements: physiological thermal niche, physiological hydrological niche, and restrictions to uncommon geological features or derivatives. Global circulation models, including Climate Wizard, project an increase in the annual average temperature across Pennsylvania within this century (UCS 2008). Warming of air temperature will likely impact species restricted to cooler terrestrial and aquatic environments. Many of the plants included in this project are limited to high elevation wetlands in the northern half of the state, a risk factor that adds to their climate change vulnerability. One mussel, the eastern pearshell, inhabits cold water trout streams where a temperature increase due to climate change will likely alter habitat quality.

Changes in moisture or hydrological regime related to climate change will likely alter habitat quality/quantity for some species. Given climate change induced temperature increases coupled with altered precipitation patterns, habitats in Pennsylvania will likely experience a seasonal net drying effect. Aquatic and semi-aquatic plants are the largest group affected by this risk factor. A few of the amphibians, turtles, and insects that depend on aquatic environments for at least a portion of the season will likely also be negatively impacted by these changes.

Restriction to uncommon habitat features (e.g., particular soil/substrate, geology, water chemistry, or specific physical features) is another risk factor that may likely increase a species vulnerability to climate change. Climate envelopes may shift away from the locations of fixed geological features or their derivatives making species tied to these uncommon features potentially more vulnerable to habitat loss from climate change than are species that thrive under diverse conditions (Young et al. 2010) A few examples of habitat specialists include: willow oak and wild limestone petunia are restricted to specific soil types that are uncommon in Pennsylvania, cave invertebrates are limited to caves, and the Allegheny woodrat typically uses rocky cliffs, talus slopes, and caves (Merritt 1987; Castleberry et al. 2001; Castleberry et al. 2002).

Interpreting CCVI Results

As discussed above, the CCVI results provide some insight into risk factors contributing to the climate change vulnerability of a species. However, additional factors should be considered in concert with the CCVI results. First, population level metrics were omitted from the risk factors included in the index. Climate change is likely to add an additional stress to species that are already experiencing population level declines. To include demographic information, the index was designed for use with NatureServe's conservation ranks (such as G-ranks and S-ranks) (Master et al. 2000). Conservation ranks are paired with index results to aid in the interpretation of overall results (see Results and Appendix 3). It is important to consider the G-ranks and S-ranks along with the CCVI score when considering species focused conservation activities.

The calculated CCVI score provides the user with an idea of the range/abundance shift that may occur within a defined area as the result of climate change. However, this shift is likely to be more complicated than the simplistic one described by the CCVI score. For instance, the CCVI considers the physical ability of a species to move to a new location, barriers to movement, and whether a species has specific ties to geologic features, but does not address whether suitable habitat is available beyond a species' current range and whether or not that habitat will remain suitable in the future as conditions change. In concert with the CCVI results, it is also necessary to consider the availability and long term stablility of suitable habitat when applying these results to future resource management efforts.

The index notes (see Appendix 3 for examples) and species' ranges (see Appendix 4) should be considered when evaluating the overall CCVI scores. For some of the southerly distributed species where Pennsylvania is the northern edge of their range, the index may indicate that these species are vulnerable (to some degree) to climate change, but that their ranges may expand in the state. For southern species at the edge of their range, as the climate warms and becomes more suitable, environmental tolerance of other stressors may increase and enable species to expand their ranges farther north. These species may occupy a larger range in the state and additional species may migrate in from surrounding southern states thus altering the current distribution and abundance in Pennsylvania. The pattern is similar for some of the northern affiliate species where Pennsylvania is the southern edge of range. As the climate warms in Pennsylvania, the CCVI suggests that some of these species will shift their ranges northward towards cooler conditions and may leave the state entirely. In terms of the ranges of species, it is also important to remember that the CCVI score is based on a defined area of interest. For this project, the defined area is the entire state of Pennsyvania. A species' sensitivity and exposure to climate change outside of Pennsylvania was not considered when calculating the CCVI score.

Another consideration when interpreting the CCVI results is that the index does not account for additional threats outside of climate change. The assessment of climate change impacts on individual species is especially challenging in light of the chances for unforeseen events that can rapidly impact species and/or entire ecosystems. A species may be moderately vulnerable or stable to short-term climate change effects, but may be highly susceptible to other threats such as diseases or habitat loss. For example, the CCVI score for the eastern small-footed bat is moderately vulnerable. The CCVI indicates that the risk factors contributing most to climate change vulnerability are impacts by wind farms built to mitigate against climate change, use of caves and mines for winter hibernacula, preference for cooler microsites within caves, and has experienced a slightly lower than average precipitation variation over the past 50 years (see Appendix 6). Unfortunately, climate change is a lesser concern for the conservation of this species. White-nose syndrome is drastically reducing populations of eastern small-foot bats so much that the United States Fish and Widlife Service is now formally evaluating the bat for federal listing as threatened or endangered.

A final consideration is the time frame by which the CCVI addresses vulnerability to climate change. The index contemplates climate change vulnerability by the year 2050, a typical cut-off date for predictions made in the International Panel on Climate Change reports (e.g., IPCC 2007). Given the positive feedback loops that are expected to amplify climate change warming trends and potential changes to complex species interactions (e.g., food webs), long-term climate change effects may be dramatically different for species from the short-term ones predicted by the CCVI.

Future Direction

This project provides insight into possible climate change effects on the biota of Pennsylvania. The findings suggest that some species are likely to respond negatively to climate change impacts while others may be unaffected or may even expand their range in the state. Since only a small subsample of Pennsylvania species was assessed in this project, future efforts should expand on the number of species examined. Additional CCVI-related projects are underway in Pennsylvania that will include more examples of the taxonomic groups presented in this report along with focusing on new groups such as fish. The combined results of these projects will provide a more detailed account of likely climate change effects on species in Pennsylvania.

Since movement of species in response to climate change is not dictated by state borders, it is also important that future work focus on regional changes in biota. It is likely that Pennsylvania will gain and lose species to surrounding states as the climate warms and understanding which species are likely to move in and out of the state is necessary for anticipating current and future conservation needs. Both the New York Natural Heritage Program (Schlesinger et al. 2011) and West Virginia Division of Natural Resources (Byers and Norris 2011) have recently completed a species level climate change assessment using the CCVI. Comparing the results of these projects along with the findings from this study will provide some insight into possible species shifts that may occur on a regional basis.

The conservation and management of species is a difficult task made even more challenging given the uncertainity of climate change impacts. However, it is necessary to incorporate climate change adaptation strategies into species conservation plans. Identifying which species are vulnerable to climate change and recognizing the risk factors associated with vulnerability are the first steps to working climate change adaptation measures into future conservation planning.

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Appendix 1. List of priority species for examination using the CCVI. Those species with asterisks next to their common names were examined in this project.

Taxa Group	Scientific Name	Common Name
Amphibians	*Acris crepitans*	Northern cricket frog
Amphibians	*Ambystoma jeffersonianum*	Jefferson salamander*
Amphibians	*Ambystoma opacum*	Marbled salamander
Amphibians	*Aneides aeneus*	Green salamander
Amphibians	*Bufo fowleri*	Fowler's toad
Amphibians	*Cryptobranchus alleganiensis*	Eastern hellbender*
Amphibians	*Hemidactylium scutatum*	Four-toed salamander
Amphibians	*Plethodon hoffmani*	Valley and ridge salamander
Amphibians	*Pseudacris brachyphona*	Mountain chorus frog*
Amphibians	*Pseudocris feriarum*	Upland chorus frog
Amphibians	*Pseudacris kalmi*	New Jersey chorus frog
Amphibians	*Pseudocris triseriata*	Striped chorus frog
Amphibians	*Rana pipiens*	Northern leopard frog
Amphibians	*Rana sphenocephala*	Coast plain leopard frog
Amphibians	*Scaphiopus holbrookii*	Eastern spadefoot*
Birds	*Ammodramus henslowii*	Henslow's sparrow*
Birds	*Anas rubripes*	American black duck
Birds	*Asio flammeus*	Short-eared owl
Birds	*Asio otus*	Long-eared owl
Birds	*Bartramia longicauda*	Upland sandpiper
Birds	*Botaurus lentiginosus*	American bittern
Birds	*Carduelis pinus*	Pine siskin
Birds	*Catharus ustulatus*	Swainson's thrush
Birds	*Charadrius melodus*	Piping plover
Birds	*Chlidonias niger*	Black tern
Birds	*Circus cyaneus*	Northern harrier
Birds	*Cistothorus palustris*	Marsh wren
Birds	*Cistothorus platensis*	Sedge wren
Birds	*Colinus virginianus*	Northern bobwhite
Birds	*Contopus cooperi*	Olive-sided flycatcher
Birds	*Cygnus columbianus*	Tundra swan*
Birds	*Dendroica cerulea*	Cerulean warbler*
Birds	*Dendroica fusca*	Blackburnian warbler
Birds	*Dendroica striata*	Blackpoll warbler
Birds	*Dendroica virens*	Black-throated green warbler
Birds	*Empidonax flaviventris*	Yellow-bellied flycatcher
Birds	*Empidonax virescens*	Acadian flycatcher
Birds	*Falco peregrinus*	Peregrine falcon
Birds	*Haliaeetus leucocephalus*	Bald eagle

Taxa Group	Scientific Name	Common Name
Birds	*Helmitheros vermivorus*	Worm eating warbler*
Birds	*Hylocichla mustelina*	Wood thrush*
Birds	*Lanius ludovicianus migrans*	Loggerhead shrike
Birds	*Loxia curvirostra*	Red crossbill
Birds	*Oporornis formosus*	Kentucky warbler
Birds	*Piranga olivacea*	Scarlet tanager*
Birds	*Piranga rubra*	Summer tanager
Birds	*Protonotaria citrea*	Prothonotary warbler
Birds	*Rallus limicola*	Virginia rail
Birds	*Seiurus motacilla*	Louisiana waterthrush*
Birds	*Spiza americana*	Dickcissel
Birds	*Sterna hirundo*	Common tern
Birds	*Troglodytes troglodytes*	Winter warbler
Birds	*Vermivora chrysoptera*	Golden-winged warbler*
Birds	*Vermivora pinus*	Blue-winged warbler*
Birds	*Vireo solitarius*	Blue-headed vireo
Birds	*Wilsonia canadensis*	Canada warbler
Fish	*Acipenser brevirostrum*	Shortnose sturgeon
Fish	*Acipenser fulvescens*	Lake sturgeon
Fish	*Acipenser oxyrinchus*	Atlantic sturgeon
Fish	*Alosa aestivalis*	Blueback herring
Fish	*Alosa mediocris*	Hickory shad
Fish	*Alosa pseudoharengus*	Alewife
Fish	*Ameiurus catus*	White catfish
Fish	*Ameiurus melas*	Black bullhead
Fish	*Ammocrypta pellucida*	Eastern sand darter
Fish	*Anguilla rostrata*	American eel
Fish	*Carpiodes carpio*	River carpsucker
Fish	*Carpiodes velifer*	Highfin carpsucker
Fish	*Catostomus catostomus*	Longnose sucker
Fish	*Cottus sp. 7*	Checkered sculpin
Fish	*Culea inconstans*	Brook stickleback
Fish	*Enneacanthus obesus*	Banded sunfish
Fish	*Erimystax dissimilis*	Streamline chub
Fish	*Erimystax x-punctatus*	Gravel chub
Fish	*Etheostoma camurum*	Bluebreast darter
Fish	*Etheostoma exile*	Iowa darter
Fish	*Etheostoma maculatum*	Spotted darter
Fish	*Etheostoma tippecanoe*	Tippecanoe darter

Taxa Group	Scientific Name	Common Name
Fish	*Exoglossum laurae*	Tonguetied minnow
Fish	*Hiodon alosoides*	Goldeye
Fish	*Hiodon tergisus*	Mooneye
Fish	*Ictiobus cyprinellus*	Bigmouth buffalo
Fish	*Ictiobus niger*	Black buffalo
Fish	*Ichthyomyzon bdellium*	Ohio lamprey
Fish	*Ichthyomyzon fossor*	Northern brook lamprey
Fish	*Ichthyomyzon greeleyi*	Mountain brook lamprey
Fish	*Lampetra aepyptera*	Least brook lamprey
Fish	*Lepisosteus oculatus*	Spotted gar
Fish	*Lepomis gulosus*	Warmouth
Fish	*Lota lota*	Burbot (Allegheny River population)
Fish	*Lythrurus umbratilis*	Redfin shiner
Fish	*Macrhybopsis storeriana*	Silver chub
Fish	*Minytrema melanops*	Spotted sucker
Fish	*Nocomis biguttatus*	Hornyhead chub
Fish	*Notropis bifrenatus*	Bridle shiner
Fish	*Notropis blennius*	River shiner
Fish	*Notropis chalybaeus*	Ironcolor shiner
Fish	*Notropis dorsalis*	Bigmouth shiner
Fish	*Notropis heterodon*	Blackchin shiner
Fish	*Noturus eleutherus*	Mountain madtom
Fish	*Noturus gyrinus*	Tadpole madtom
Fish	*Noturus miurus*	Brindled madtom
Fish	*Noturus stigmosus*	Northern madtom
Fish	*Osmerus mordax*	Rainbow smelt
Fish	*Pararhinichtys bowersi*	Cheat minnow
Fish	*Percina caprodes*	Chesapeak logperch
Fish	*Percina copelandi*	Channel darter
Fish	*Percina evides*	Gilt darter
Fish	*Percina macrocephala*	Longhead darter*
Fish	*Phoxinus erythrogaster*	Southern redbelly dace
Fish	*Polyodon spathula*	Paddlefish
Invertebrates	*Acroneuria arida*	--
Invertebrates	*Allocapnia simmonsi*	--
Invertebrates	*Alloperla aracoma*	--
Invertebrates	*Alloperla vostoki*	--
Invertebrates	*Ameletus browni*	--

Taxa Group	Scientific Name	Common Name
Invertebrates	*Amnicola decisus*	--
Invertebrates	*Caecidotea franzi*	Franz's cave isopod
Invertebrates	*Caecidotea kenki*	An isopod*
Invertebrates	*Caecidotea pricei*	Price's Cave isopod
Invertebrates	*Calephelis borealis*	Northern metalmark*
Invertebrates	*Callophrys irus*	Frosted elfin*
Invertebrates	*Calycopis cecrops*	Red-banded hairstreak*
Invertebrates	*Cambarus monongalensis*	Monongahela crayfish
Invertebrates	*Carychium nannodes*	File thorn
Invertebrates	*Catocala dulciola*	--
Invertebrates	*Centroptilum semirufum*	A mayfly
Invertebrates	*Ceraclea alabamae*	A caddisfly
Invertebrates	*Ceraclea albosticta*	--
Invertebrates	*Cerma cora*	A bird-dropping moth
Invertebrates	*Chaetaglaea cerata*	A sallow moth
Invertebrates	*Cheumatopsyche helma*	Helma's cheumatopsyche caddisfly
Invertebrates	*Cheumatopsyche vannotei*	Vannote's cheumatopsyche caddisfly
Invertebrates	*Cicindela abdominalis*	Eastern pinebarrens tiger beetle
Invertebrates	*Cicindela ancocisconensis*	Appalachian tiger beetle*
Invertebrates	*Cicindela lepida*	Ghost tiger beetle
Invertebrates	*Cicindela marginipennis*	Cobblestone tiger beetle*
Invertebrates	*Cicindela patruela*	Northern barrens tiger beetle*
Invertebrates	*Crangonyx dearolfi*	Pennsylvania cave amphipod
Invertebrates	*Datana ranaeceps*	A hand-maid moth
Invertebrates	*Enallagma laterale*	New England bluet
Invertebrates	*Erora laeta*	Early hairstreak
Invertebrates	*Erynnis martialis*	Mottled duskywing
Invertebrates	*Erynnis persius persius*	Persius duskywing
Invertebrates	*Eurylophella bicoloroides*	--
Invertebrates	*Eurylophella poconoensis*	--
Invertebrates	*Fontigens orolibas*	Blue Ridge springsnail
Invertebrates	*Glyphyalinia raderi*	Maryland glyph
Invertebrates	*Gomphus abbreviatus*	Spine-crowned clubtail
Invertebrates	*Gomphus quadricolor*	Rapids clubtail*
Invertebrates	*Gomphus viridifrons*	Green-faced clubtail*
Invertebrates	*Hansonoperla appalachia*	--
Invertebrates	*Heliomata infulata*	--
Invertebrates	*Hemaris gracilis*	Graceful clearwing
Invertebrates	*Hemileuca nevadensis*	--

Taxa Group	Scientific Name	Common Name
Invertebrates	*Hemileuca nevadensis ssp. 3*	Midwestern fen buckmoth
Invertebrates	*Heptagenia culacantha*	--
Invertebrates	*Hesperia attalus*	Dotted skipper
Invertebrates	*Hesperia attalus slossonae*	Dotted skipper
Invertebrates	*Heteromeyenia longistylus*	Pennsylvania sponge
Invertebrates	*Holomelina nigricans*	--
Invertebrates	*Isogenoides olivaceus*	--
Invertebrates	*Isonychia hoffmani*	
Invertebrates	*Itame sp. 1 nr. inextricata*	Barrens itame (Cf I. Inextricata)
Invertebrates	*Lemmeria digitalis*	Fingered lemmeria moth
Invertebrates	*Leucotrichia pictipes*	A micro caddisfly
Invertebrates	*Lithasia obovata*	Shawnee rocksnail
Invertebrates	*Lithophane franclemonti*	--
Invertebrates	*Lycaena epixanthe*	Bog copper*
Invertebrates	*Lyogyrus walkeri*	--
Invertebrates	*Megaleuctra flinti*	--
Invertebrates	*Merolonche dolli*	Doll's merolonche
Invertebrates	*Metarranthis apiciaria*	Barrens metarranthis moth
Invertebrates	*Nicrophorus americanus*	American burying beetle
Invertebrates	*Ophiogomphus anomalus*	Extra-striped snaketail
Invertebrates	*Ophiogomphus howei*	Pygmy dragonfly
Invertebrates	*Ophiogomphus incurvatus*	Appalachian snaketail
Invertebrates	*Ostrocerca prolongata*	--
Invertebrates	*Oxyloma subeffusum*	--
Invertebrates	*Papaipema aerata*	A borer moth
Invertebrates	*Papaipema araliae*	--
Invertebrates	*Papaipema astuta*	--
Invertebrates	*Papaipema duplicata*	--
Invertebrates	*Papaipema maritima*	--
Invertebrates	*Papaipema sp. 1*	Flypoison borer moth*
Invertebrates	*Papaipema sp. 2 nr. pterisii*	--
Invertebrates	*Paravitrea lacteodens*	--
Invertebrates	*Perlesta nitida*	--
Invertebrates	*Perlesta teaysia*	Teays stonefly
Invertebrates	*Pieris virginiensis*	West Virginia white*
Invertebrates	*Psectraglaea carnosa*	Pink sallow
Invertebrates	*Pteronarcys comstocki*	--
Invertebrates	*Pyrgus wyandot*	Appalachian grizzled skipper*
Invertebrates	*Rhyacophila otica*	--

Taxa Group	Scientific Name	Common Name
Invertebrates	*Somatogyrus pennsylvanicus*	Shale pebblesnail
Invertebrates	*Soyedina merritti*	A stonefly
Invertebrates	*Speyeria diana*	Diana fritillary
Invertebrates	*Speyeria idalia*	Regal fritillary*
Invertebrates	*Sphalloplana pricei*	Refton Cave planarian*
Invertebrates	*Stygobromus allegheniensis*	Allegheny Cave amphipod
Invertebrates	*Stygobromus biggersi*	Biggers' Cave amphipod
Invertebrates	*Stygobromus franzi*	Franz's Cave amphipod
Invertebrates	*Stygobromus gracilipes*	Shenandoah Valley Cave amphipod
Invertebrates	*Stygobromus pizzinii*	Pizzini's Cave amphipod
Invertebrates	*Stygobromus stellmacki*	Stellmack's Cave amphipod*
Invertebrates	*Succinea pennsylvanica*	--
Invertebrates	*Triodopsis picea*	--
Invertebrates	*Utaperla gaspesiana*	--
Invertebrates	*Valvata perdepressa*	--
Invertebrates	*Vertigo bollesiana*	--
Invertebrates	*Zale curema*	Northeastern pine zale*
Invertebrates	*Zale sp. 1 nr. lunifera*	Pine barrens zale
Mammals	*Cryptotis parva*	Least shrew
Mammals	*Glaucomys sabrinus*	Northern flying squirrel
Mammals	*Lasionycteris noctivagans*	Silver-haired bat
Mammals	*Lasiurus borealis*	Eastern red bat
Mammals	*Lasiurus cinereus*	Hoary bat
Mammals	*Lepus americanus*	Snowshoe hare*
Mammals	*Microtus chrotorrhinus*	Rock vole
Mammals	*Myotis leibii*	Eastern small-footed myotis*
Mammals	*Myotis septentrionalis*	Northern long-eared bat
Mammals	*Myotis sodalis*	Indiana or Social myotis
Mammals	*Mustela nivalis*	Least weasel
Mammals	*Neotoma magister*	Allegheny woodrat*
Mammals	*Sciurus niger vulpinus*	Eastern fox squirrel
Mammals	*Sciurus n. niger*	Southern fox squirrel
Mammals	*Sorex dispar*	Rock shrew
Mammals	*Sorex palustris albibarbis*	Northern water shrew
Mammals	*Sorex palustris punctulatus*	Southern water shrew
Mammals	*Sylvilagus obscurus*	Appalachian cottontail*
Mammals	*Synaptomys cooperi*	Southern bog lemming

Taxa Group	Scientific Name	Common Name
Mussels	*Alasmidonta heterodon*	Dwarf wedgemussel*
Mussels	*Alasmidonta undulata*	Triangle floater
Mussels	*Alasmidonta varicosa*	Brook floater
Mussels	*Ellipsaria lineolata*	Butterfly
Mussels	*Elliptio fisheriana*	Northern lance
Mussels	*Elliptio producta*	Atlantic spike
Mussels	*Epioblasma torulosa*	Tubercled blossom
Mussels	*Epioblasma torulosa rangiana*	Northern riffleshell*
Mussels	*Epioblasma triquetra*	Snuffbox
Mussels	*Fusconaia subrotunda*	Longsolid
Mussels	*Lampsilis cariosa*	Yellow lampmussel*
Mussels	*Lasmigona subviridis*	Green floater
Mussels	*Ligumia nasuta*	Eastern pondmussel
Mussels	*Margaritifera margaritifera*	Eastern pearlshell*
Mussels	*Obovaria subrotunda*	Round hickorynut
Mussels	*Plethobasus cyphyus*	Sheepnose
Mussels	*Pleurobema clava*	Clubshell*
Mussels	*Pleurobema sintoxia*	Round pigtoe
Mussels	*Quadrula cylindrica cylindrica*	Rabbitsfoot
Mussels	*Simpsonaias ambigua*	Salamander mussel
Mussels	*Tritogonia verrucosa*	Pistolgrip
Mussels	*Villosa fabalis*	Rayed bean*
Reptiles	*Clemmys guttata*	Spotted turtle*
Reptiles	*Clonophis kirtlandii*	Kirtland's snake
Reptiles	*Crotalus horridus*	Timber rattlesnake*
Reptiles	*Emys blandingii*	Blanding's turtle
Reptiles	*Eumeces anthracinus*	Coal skink
Reptiles	*Eumeces laticeps*	Broadhead skink
Reptiles	*Glyptemys insculpta*	Wood turtle*
Reptiles	*Glyptemys muhlenbergii*	Bog turtle*
Reptiles	*Graptemys geographica*	Map turtle
Reptiles	*Heterodon platirhinos*	Eastern hognose snake
Reptiles	*Opheodrys aestivus*	Rough green snake
Reptiles	*Pseudemys rubriventris*	Redbelly turtle
Reptiles	*Regina septemvittata*	Queen snake
Reptiles	*Sceloporus undulatus*	Eastern fence lizard
Reptiles	*Sistrurus catenatus catenatus*	Eastern massasauga
Reptiles	*Thamnophis brachystoma*	Shorthead garter snake

Taxa Group	Scientific Name	Common Name
Reptiles	*Thamnophis sauritus*	Eastern ribbon snake
Reptiles	*Virginia valeriae pulchra*	Mountain earth snake
Plants	*Actaea rubra*	Red baneberry
Plants	*Abies balsamea*	Balsam fir
Plants	*Alnus incana*	Speckled alder
Plants	*Alnus viridis*	Mountain alder
Plants	*Amelanchier bartramiana*	Mountain juneberry
Plants	*Andromeda polifolia*	Bog-rosemary*
Plants	*Andropogon gyrans*	Elliott's beardgrass*
Plants	*Arceuthobium pusillum*	Dwarf mistletoe*
Plants	*Arctostaphylos uva-ursi*	Bearberry
Plants	*Arethusa bulbosa*	Dragon's-mouth
Plants	*Argentina anserina*	Silverweed cinquefoil
Plants	*Astragalus neglectus*	Cooper's milk-vetch
Plants	*Bartonia paniculata*	Screwstem*
Plants	*Betula papyrifera*	Paper birch
Plants	*Bidens beckii*	Beck's water-marigold
Plants	*Calla palustris*	Wild calla
Plants	*Carex adusta*	Crowded sedge
Plants	*Carex arctata*	Sedge
Plants	*Carex atherodes*	Awned sedge
Plants	*Carex aurea*	Golden-fruited sedge
Plants	*Carex backii*	Back's sedge
Plants	*Carex bebbii*	Bebb's sedge
Plants	*Carex cephaloidea*	Sedge
Plants	*Carex chordorrhiza*	Creeping sedge
Plants	*Carex crawfordii*	Crawford's sedge
Plants	*Carex cryptolepis*	Northeastern sedge
Plants	*Carex cumulata*	Sedge
Plants	*Carex deweyana*	Sedge
Plants	*Carex diandra*	Lesser panicled sedge*
Plants	*Carex disperma*	Soft-leaved sedge*
Plants	*Carex flava*	Yellow sedge
Plants	*Carex foenea*	Fernald's hay sedge
Plants	*Carex formosa*	Handsome sedge
Plants	*Carex garberi*	Elk sedge
Plants	*Carex geyeri*	Geyer's sedge
Plants	*Carex gynocrates*	Northern bog sedge

Taxa Group	Scientific Name	Common Name
Plants	*Carex haydenii*	Cloud sedge
Plants	*Carex lasiocarpa*	Many-fruited sedge*
Plants	*Carex leptonervia*	Sedge
Plants	*Carex limosa*	Mud sedge*
Plants	*Carex novae-angliae*	Sedge
Plants	*Carex oligosperma*	Few-seeded sedge*
Plants	*Carex ormostachya*	Spike sedge
Plants	*Carex pallescens*	Sedge
Plants	*Carex pauciflora*	Few-flowered sedge
Plants	*Carex paupercula*	Bog sedge*
Plants	*Carex pedunculata*	Sedge
Plants	*Carex polymorpha*	Variable sedge
Plants	*Carex prairea*	Prairie sedge
Plants	*Carex pseudocyperus*	Cyperus-like sedge
Plants	*Carex retrorsa*	Backward sedge
Plants	*Carex richardsonii*	Sedge
Plants	*Carex sartwellii*	Sartwell's sedge
Plants	*Carex schweinitzii*	Schweinitz' sedge
Plants	*Carex siccata*	Sedge
Plants	*Carex sprengelii*	Sedge
Plants	*Carex sterilis*	Atlantic sedge
Plants	*Carex tetanica*	Wood's sedge
Plants	*Carex tuckermanii*	Sedge
Plants	*Carex utriculata*	Sedge
Plants	*Carex viridula*	Green sedge
Plants	*Carex wiegandii*	Wiegand's sedge
Plants	*Chamaedaphne calyculata*	Leatherleaf*
Plants	*Chenopodium capitatum*	Indian-paint
Plants	*Chenopodium foggii*	Goosefoot
Plants	*Clematis occidentalis*	Purple clematis
Plants	*Comarum palustre*	Purple marlocks
Plants	*Conioselinum chinense*	Hemlock-parsley
Plants	*Conoclinium coelestinum*	Mistflower*
Plants	*Coptis trifolia*	Goldthread*
Plants	*Corallorhiza trifida*	Early coralroot
Plants	*Cornus canadensis*	Bunchberry*
Plants	*Cornus rugosa*	Round-leaved dogwood
Plants	*Cryptogramma stelleri*	Slender rockbrake
Plants	*Cyperus houghtonii*	Houghton's flatsedge

Taxa Group	Scientific Name	Common Name
Plants	*Cypripedium candidum*	Small white lady's-slipper
Plants	*Cypripedium reginae*	Large white lady's-slipper
Plants	*Cystopteris fragilis*	Fragile fern
Plants	*Cystopteris laurentiana*	Laurentian bladder fern
Plants	*Dalibarda repens*	Dewdrop*
Plants	*Deschampsia cespitosa*	Tufted hairgrass
Plants	*Dicanthelium boreale*	Northern panic grass
Plants	*Dichanthelium leibergii*	Leiberg's panic grass
Plants	*Dichanthelium xanthophysum*	Slender panic grass
Plants	*Diphasiastrum sabinifolium*	Savinleaf groundpine
Plants	*Dodecatheon radicatum*	Jeweled shooting star*
Plants	*Elatine minima*	Small waterwort
Plants	*Eleocharis intermedia*	Matted spike-rush
Plants	*Eleocharis quinqueflora*	Spike-rush
Plants	*Elymus trachycaulus*	Slender wheatgrass
Plants	*Elymus wiegandii*	Canada wild-rye
Plants	*Epilobium palustre*	Marsh willow-herb
Plants	*Epilobium strictum*	Downy willow-herb
Plants	*Equisetum fluviatile*	Water horsetail
Plants	*Equisetum sylvaticum*	Woodland horsetail
Plants	*Equisetum variegatum*	Variegated horsetail
Plants	*Eriocaulon aquaticum*	Seven-angle pipewort
Plants	*Eriophorum gracile*	Slender cotton-grass
Plants	*Eriophorum tenellum*	Rough cotton-grass
Plants	*Eriophorum vaginatum*	Cotton-grass
Plants	*Eriophorum virginicum*	Tawny cotton-grass*
Plants	*Eriophorum viridicarinatum*	Thin-leaved cotton-grass
Plants	*Erythronium albidum*	White trout lily*
Plants	*Fallopia convulvulus*	Black bindweed
Plants	*Galium labradoricum*	Bog bedstraw
Plants	*Galium latifolium*	Purple bedstraw*
Plants	*Galium palustre*	Ditch bedstraw
Plants	*Galium trifidum*	Cleavers*
Plants	*Gaultheria hispidula*	Creeping snowberry*
Plants	*Gentianopsis crinita*	Eastern fringed gentian
Plants	*Gentianopsis virgata*	Narrow-leaved fringed gentian
Plants	*Geranium bicknellii*	Cranesbill
Plants	*Geum rivale*	Water avens
Plants	*Glyceria borealis*	Northern mannagrass

Taxa Group	Scientific Name	Common Name
Plants	*Glyceria grandis*	American mannagrass
Plants	*Goodyera repens*	Lesser rattlesnake-plantain
Plants	*Goodyera tesselata*	Checkered rattlesnake-plantain
Plants	*Gymnocarpium dryopteris*	Common oak fern
Plants	*Gymnocarpium x heterosporum*	Oak fern
Plants	*Hieracium umbellatum*	Canada hawkweed
Plants	*Hierochloe odorata*	Vanilla sweetgrass
Plants	*Hypericum majus*	Canadian St. John's-wort
Plants	*Ilex mucronata*	Mountain holly
Plants	*Juncus alpinoarticulatus*	Alpine rush
Plants	*Juncus arcticus*	Baltic rush
Plants	*Juncus biflorus*	Grass rush*
Plants	*Juncus brachycephalus*	Small-headed rush
Plants	*Juncus filiformis*	Thread rush*
Plants	*Juncus greenei*	Greene's rush
Plants	*Juncus militaris*	Bayonet rush
Plants	*Kalmia angustifolia*	Sheep laurel
Plants	*Kalmia polifolia*	Bog laurel*
Plants	*Larix laricina*	American larch
Plants	*Lathyrus japonicus*	Beach pea
Plants	*Lathyrus ochroleucus*	Wild pea
Plants	*Linnaea borealis*	Twinflower
Plants	*Listera cordata*	Heartleaf twayblade
Plants	*Lobelia dortmanna*	Water lobelia
Plants	*Lobelia kalmii*	Brook lobelia
Plants	*Lonicera hirsuta*	Hairy honeysuckle
Plants	*Lonicera oblongifolia*	Swamp fly honeysuckle
Plants	*Lonicera villosa*	Water-berry
Plants	*Maianthemum stellatum*	Starflower
Plants	*Maianthemum trifolium*	False solomon's-seal*
Plants	*Malaxis bayardii*	Adder's-mouth
Plants	*Malaxis brachypoda*	White adder's-mouth
Plants	*Matteuccia struthiopteris*	Ostrich fern
Plants	*Menyanthes trifolia*	Bogbean
Plants	*Milium effusum*	Milletgrass
Plants	*Mitella nuda*	Bishop's-cap
Plants	*Moehringia lateriflora*	Blunt-leaved sandwort
Plants	*Montia chamissoi*	Chamisso's miner's-lettuce
Plants	*Muhlenbergia uniflora*	Fall dropseed muhly*

Taxa Group	Scientific Name	Common Name
Plants	*Myrica gale*	Sweet-gale
Plants	*Myrica pensylvanica*	Bayberry
Plants	*Myriophyllum farwellii*	Farwell's water-milfoil
Plants	*Myriophyllum humile*	Water-milfoil
Plants	*Myriophyllum sibiricum*	Northern water-milfoil
Plants	*Myriophyllum tenellum*	Slender water-milfoil
Plants	*Myriophyllum verticillatum*	Whorled water-milfoil
Plants	*Oclemena nemoralis*	Leafy bog aster*
Plants	*Omalotheca sylvatica*	Woodland cudweed
Plants	*Orthilia secunda*	One-sided shinleaf
Plants	*Oryzopsis asperifolia*	Spreading ricegrass
Plants	*Parnassia glauca*	Grass-of-parnassus
Plants	*Persicaria careyi*	Pinkweed
Plants	*Phegopteris connectilis*	Long beech fern
Plants	*Picea mariana*	Black spruce*
Plants	*Picea rubens*	Red spruce*
Plants	*Pinus resinosa*	Norway pine
Plants	*Piptatherum pungens*	Slender mountain ricegrass
Plants	*Platanthera blephariglottis*	White fringed-orchid*
Plants	*Platanthera dilatata*	Tall white bog-orchid
Plants	*Platanthera hookeri*	Hooker's orchid
Plants	*Platanthera huronensis*	Tall green bog-orchid
Plants	*Platanthera leucophaea*	Eastern prairie fringed-orchid
Plants	*Poa paludigena*	Bog bluegrass
Plants	*Poa saltuensis*	Old-pasture bluegrass
Plants	*Polemonium vanbruntiae*	Jacob's-ladder
Plants	*Polystichum braunii*	Braun's holly fern
Plants	*Populus balsamifera*	Balsam poplar
Plants	*Potamogeton confervoides*	Tuckerman's pondweed
Plants	*Potamogeton friesii*	Fries' pondweed
Plants	*Potamogeton gramineus*	Grassy pondweed
Plants	*Potamogeton hillii*	Hill's pondweed
Plants	*Potamogeton oakesianus*	Oakes' pondweed
Plants	*Potamogeton obtusifolius*	Blunt-leaved pondweed
Plants	*Potamogeton perfoliatus*	Perfoliate pondweed
Plants	*Potamogeton praelongus*	White-stem pondweed
Plants	*Potamogeton robbinsii*	Flat-leaved pondweed
Plants	*Potamogeton strictifolius*	Narrow-leaved pondweed
Plants	*Potamogeton vaseyi*	Vasey's pondweed

Taxa Group	Scientific Name	Common Name
Plants	*Potentilla fruticosa*	Shrubby cinquefoil
Plants	*Potentilla paradoxa*	Bushy cinquefoil
Plants	*Prenanthes racemosa*	Glaucous rattlesnake-root
Plants	*Prunus pumila* var. *depressa*	Eastern sand cherry*
Plants	*Pseudognaphalium macounii*	Fragrant cudweed
Plants	*Pyrola chlorantha*	Wintergreen
Plants	*Quercus phellos*	Willow oak*
Plants	*Ranunculus flammula*	Creeping spearwort
Plants	*Ranunculus pensylvanicus*	Bristly crowfoot
Plants	*Rhamnus alnifolia*	Alder-leaved buckthorn
Plants	*Rhododendron canadense*	Rhodora*
Plants	*Rhododendron groenlandicum*	Labrador-tea*
Plants	*Phynchospora alba*	White beak-rush*
Plants	*Ribes hirtellum*	Northern wild gooseberry
Plants	*Ribes lacustre*	Bristly black currant
Plants	*Ribes triste*	Wild red currant
Plants	*Rotala ramosior*	Toothcup*
Plants	*Rubus pubescens*	Dwarf blackberry
Plants	*Ruellia strepens*	Wild limestone petunia*
Plants	*Salix amygdaloides*	Peach-leaved willow
Plants	*Salix candida*	Hoary willow
Plants	*Salix lucida*	Shining willow
Plants	*Salix myricoides*	Broad-leaved willow
Plants	*Salix pedicellaris*	Bog willow
Plants	*Salix petiolaris*	Meadow willow*
Plants	*Salix serissima*	Autumn willow
Plants	*Saxifraga pensylvanica*	Swamp saxifrage
Plants	*Scheuchzeria palustris*	Pod-grass*
Plants	*Schizachne purpurascens*	Grass
Plants	*Schoenoplectus heterochaetus*	Slender bulrush
Plants	*Schoenoplectus subterminalis*	Water bulrush*
Plants	*Schoenoplectus torreyi*	Torrey's bulrush
Plants	*Scirpus ancistrochaetus*	Northeastern bulrush*
Plants	*Shepherdia canadensis*	Buffalo-berry
Plants	*Sisyrinchium montanum*	Blue-eyed-grass
Plants	*Solidago uliginosa*	Bog goldenrod*
Plants	*Sorbus decora*	Showy mountain-ash
Plants	*Sparganium angustifolium*	Bur-reed
Plants	*Spiranthes casei*	Case's ladies'-tresses

Taxa Group	Scientific Name	Common Name
Plants	*Spiranthes romanzoffiana*	Hooded ladies'-tresses
Plants	*Stellaria borealis*	Northern stitchwort
Plants	*Streptopus amplexifolius*	Twisted-stalk
Plants	*Symphyotrichum boreale*	Northern bog aster
Plants	*Taxus canadensis*	Canadian yew
Plants	*Thelypteris simulata*	Massachusetts fern
Plants	*Tipularia discolor*	Cranefly orchid*
Plants	*Triglochin palustre*	Marsh arrow-grass
Plants	*Trisetum spicatum*	Oatgrass
Plants	*Trollius laxus*	Spreading globe-flower
Plants	*Utricularia cornuta*	Horned bladderwort*
Plants	*Utricularia intermedia*	Flat-leaved bladderwort
Plants	*Utricularia minor*	Lesser bladderwort
Plants	*Vaccinium macrocarpon*	Cranberry*
Plants	*Vaccinium myrtilloides*	Sour-top blueberry
Plants	*Vaccinium oxycoccos*	Small cranberry*
Plants	*Viburnum lentago*	Nannyberry
Plants	*Viburnum trilobum*	Highbush-cranberry*
Plants	*Viola renifolia*	Kidney-leaved violet
Plants	*Viola selkirkii*	Great-spurred violet*
Plants	*Woodsia ilvensis*	Rusty woodsia
Plants	*Xyris montana*	Yellow-eyed-grass

Appendix 2. Definitions and symbols for global, state, and CCVI ranks used in the document tables.

NatureServe Conservation Status Ranks

G1, S1 Critically imperiled globally or in the state because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as a steep population decline making it especially vulnerable to extirpation.

G2, S2 Imperiled globally or in the state because of rarity due to very restricted range, very few populations (often 20 or less), steep population declines, or other factors making it very vulnerable to extirpation.

G3, S3 Vulnerable globally or in the state due to restricted range, relatively few populations (often 80 or less), recent and widespread declines, or other factors making it vulnerable to extinction.

G4, S4 Apparently secure species are uncommon but not rare but there is some cause for concern due to declines or other factors.

G5, S5 Secure species are common, widespread, and abundant globally or in the state.

Vulnerability Index Scores

EV Extremely Vulnerable – Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.
HV Highly Vulnerable – Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.
MV Moderately Vulnerable – Abundance and/or range extent within geographical area assessed likely to decrease by 2050.
PS Not Vulnerable/Presumed Stable – Available evidence does not suggest that abundance and/or range extent within geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.
IL Not Vulnerable/Increase Likely – Available evidence suggests that abundance and/or range extent within geographical area assessed is likely to increase by 2050.
IE Insufficient Evidence – Available information about a species' vulnerability is inadequate to calculate an Index score.

Individual Risk Factor Scores

GI Greatly Increase Vulnerability
Inc Increase Vulnerability

SI	Somewhat Increase Vulnerability
N	Neutral
SD	Somewhat Decrease Vulnerability
Dec	Decrease Vulnerability
N/A	Not Applicable
U	Unknown

Appendix 3. Vulnerability index scores. (Scores are defined in Appendix 2.)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Abies balsamea (Balsam fir)	G5	S3	EV	Mod	Species range may shift and perhaps leave the assessment area.	PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Uchytil 1991 (background information); Frank 1990 (seed dispersal)
Alasmidonta heterdon (Dwarf wedgemussel)	G1G2	S1	HV	VH		NatureServe Explorer database (distribution and threats); Spoo 2008 (ecology, distribution); PNHP database (distribution); NYNHP Conservation Guides (background information); US FWS 1993 (background information from recovery plan)
Ambystoma jeffersonianum (Jefferson salamander)	G4	S4	HV	Low		Used 2008 IUCN red list distribution, which includes the entire state of PA. Semlitsch 2008, Maret 2010.
Ammodramus henslowii (Henslow's sparrow)	G4	S4B	IL	VH		Atlas of Breeding Birds in PA (distribution, background information); McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats)
Andromeda polifolia (Bog-rosemary)	G5	S3	EV	VH		PNHP database; NatureServe Explorer
Arceuthobium pusillum (Dwarf mistletoe)	G5	S2	HV	Low		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Kuijt 1955 (ecology)
Bartonia paniculata (Screwstem)	G5	S3	MV	Mod		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Hill 2003 (background information)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Caecidotea kenki (an isopod)	G3	S1	PS	VH		Byers and Norris 2011, Hutchins and Culver 2007, NatureServe Explorer 2008, NatureServe 2010, Thorp and Covich (eds) 1991. See also the INVERTS additional CCVI documentation spreadsheet and the Kenki Isopod summary word document.
Calephelis borealis (Northern metalmark)	G3G4	S2	MV	Mod	Species may expand range in assessment area.	Allen 1997, Landis and Fiedler 2006, NatureServe Explorer 2008, Rhoads and Block 2000, Shortle et al. 2009. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Northern Metalmark summary word document.
Callophrys irus (Frosted elfin)	G3	S1S2	PS	VH		Allen 1997, NatureServe 2008, Swengel 1998, Schweitzer 2004, Shortle et al. 2009. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Frosted Elfin summary word document.
Calycopis cecrops (Red-banded hairstreak)	G5	S4	IL	VH		Brock and Kaufman 2003, Connecticut Butterfly Association 2007, Kessler 2000, Pyle 1981, Shortle et al. 2009. See also the INVERTS additional CCVI documentation spreadsheet and the Red-banded Hairstreak summary word document.
Carex limosa (Mud sedge)	G5	S2	EV	Low		Rhoads and Block 2007 (habitat); Rhoads and Klein 1993 (distribution); PNHP database; NatureServe Explorer (distribution); Gleason and Cronquist 1991 (pollination); Gage and Cooper 2006 (ecology); Ridley 1930 (pollination)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Carex oligosperma (Few-seeded sedge)	G5	S2	EV	VH		PNHP database and fact sheet from 2007; NatureServe Explorer (distribution); Gleason and Cronquist 1991 (pollination); Gage and Cooper 2006 (ecology)
Carex paupercula (Bog sedge)	G5	S3	HV	High		PNHP database and fact sheet from 2007; NatureServe Explorer (distribution); Gleason and Cronquist 1991 (pollination); Ridley 1930 (dispersal); Gage and Cooper 2006 (ecology)
Chamaedaphne calyculata (Leatherleaf)	G5	SNR	MV	VH		Rhoads and Block 2007 (habitat description); Rhoads and Klein 1993 (distribution in PA); NatureServe 2011 (ranks); Pavek 1993 (ecology and seed dispersal); Selosse et al. 2007 (mycorrhizal associations)
Cicindela ancocisconensis (Appalachian tiger beetle)	G3	S1	MV	VH		Allen and Acciavatti 2002 , NatureServe Explorer, NatureServe 2010, Pearson et al. 2006, Parker and Skinner 2005, Shortle et al. 2009, Pearson and Volger 2001. See also the INVERTS additional CCVI documentation spreadsheet and the Appalachian Tiger Beetle summary word document.
Cicindela marginipennis (Cobblestone tiger beetle)	G2	S1	MV	High		Allen and Acciavatti 2002 , NatureServe Explorer, NatureServe 2010, Pearson et al. 2006, Parker and Skinner 2005, Shortle et al. 2009, Pearson and Volger 2001. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Cobblestone Tiger Beetle summary word document.

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Cicindela patruela (Northern barrens tiger beetle)	G3	S2S3	PS	VH		Allen & Acciavatti 2002, NatureServe Explorer, Pearson et al. 2006, Shortle et al. 2009. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Northern Barrens Tiger Beetle summary word document.
Clemmys guttata (Spotted turtle)	G5	S3	MV	Mod		Distribution mapped using Hulse et al 2001, and PNHP data; in western PA PNHP data are lacking, so the distribution was mapped using a conservative estimate adhering closely to historical voucher records. NatureServe 2010, Maret 2010
Conoclinum coelestinum (Mistflower)	G5	S3	PS	VH	Species may expand range in assessment area.	PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat)
Coptis trifolia (Goldthread)	G5	SNR	HV	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Stein 1998 (background information); Malloch and Malloch 1981 (mycorrhizal associations); Hossler 2010 (mycorrhizal associations)
Cornus canadensis (Bunchberry)	G5	SNR	MV	Mod	Species range may shift and perhaps leave the assessment area.	PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Summerbell 1989 (mycorrhizal associations); Andreas 1983 (background information)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Crotalus horridus (Timber rattlesnake)	G4	S3S4	PS	High		Distribution map created using PNHP CRHO data. Clark et al. 2010. Reinert, 2010. Martin pers. comm.
Cryptobranchus alleganiensis (Eastern hellbender)	G3G4	S3	EV	VH		Current PNHP data are known to be lacking, so used county-level IUCN 2008 red-list distribution maps. Includes some areas probably w/o CRAL, but encompases range, including likely historic and potentially current but undocumented populations. Used northern edge of range although a few populations exist in NY. Using Center of range gets same results.Nickerson & Mays 1973, Foster (2006) Petokas 2008), Merkle et al. 1977; Routman et al 1994
Cygnus columbianus (Tundra swan)	G5	S3	IL	Low		McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats); Collins and Downes 2009; Earnst and Rothe 2004
Dalibarda repens (Dewdrop)	G5	SNR	EV	Low		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Hossler 2010 (mycorrhizal associations)
Dendroica cerulean (Cerulean warbler)	G4	S4	PS	VH		Atlas of Breeding Birds in PA (distribution, background information); McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Epioblasma torulosa rangiana (Northern riffleshell)	G2	S2	HV	VH		NatureServe Explorer database (distribution and threats); Spoo 2008 (ecology, distribution); PNHP database (distribution); NYNHP Conservation Guides (background information); US FWS 1994 (background information from recovery plan)
Eriophorum virginicum (Tawny cotton-grass)	G5	SNR	PS	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat)
Erythornium albidum (White trout-lily)	G5	S3	MV	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Morley 1982 (seed production and dispersal); Muller 1979 (background information); Thompson 1981 (seed dispersal)
Galium latifolium (Purple bedstraw)	G5	S3	PS	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Gucker 2005 (seed dispersal, background information)
Gaultheria hispidula (Creeping snowberry)	G5	S3	EV	VH		PNHP database and fact sheet; Rhoads and Block 2007; Hays 2001 (ecology and seed production and dispersal)
Glyptemys insculpta (Wood turtle)	G4	S3S4	PS	Mod		Distribution is drawn to represent that in Hulse et al. 2001; essentially all of PA except southwestern Green County.[Ernst and McBreen 1991, Mitchell 1991 Tuttle 1996. in NatureServe 2010]

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Glyptemys muhlenbergii (Bog turtle)	G3	S2	HV	High		Distribution modeled using PNHP data, exclusive of the 3 occurrences in NW PA, those having been assessed by experts as likely extirpated. Drasher and Pluto 2010, NS 2010, UCS 2008.
Gomphus quadricolor (Rapids clubtail)	G3G4	S1S2	MV	VH		COSEWIC 2008, Dunkle 2000, NatureServe Explorer, Nikula et al. 2003, Rosche et al. 2008, Shortle et al. 2009. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Rapids Clubtail summary word document.
Gomphus viridifrons (Green-faced clubtail)	G3G4	S1	MV	VH		Dunkle 2000, Evans 2002, NatureServe Explorer 2008, Rawlins 2007, Rosche 2007, Rosche et al. 2008, Shortle et al. 2009. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Green-faced Clubtail summary word document.
Helmitheros vermivorus (Worm-eating warbler)	G5	S4B	PS	VH	Species may expand range in assessment area.	McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats); Brauning 1992 (distribution and background information)
Hylocichla mustelina (Wood thrush)	G5	S5B	IL	VH		McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats)
Glyptemys muhlenbergii (Bog turtle)	G3	S2	HV	High		Distribution modeled using PNHP data, exclusive of the 3 occurrences in NW PA, those having been assessed by experts as likely extirpated. Drasher and Pluto 2010, NS 2010, UCS 2008.

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Juncus filiformis (Thread rush)	G5	S3	MV	VH		PNHP database (range); Gleason 1952 (habitat information); Hayes 2001 (habitat information); NatureServe Explorer (threats); Richards 1943 (seed production and dispersal); Rhoads and Block 2007 (habitat description); Wisheu and Keddy 1991 (seed dispersal and distribution)
Kalmia polifolia (Bog laurel)	G5	S4/S5	EV	VH		NatureServe Explorer; Largent et al. 1980 (mycorrhizal associations); Rhoads and Klein 1993 (distribution); Campbell et al. 2003 (seed dispersal); Largent et al. 1980 (mycorrhizal association)
Lampsilis cariosa (Yellow lampmussel)	G3G4	S3S4	HV	VH		NatureServe Explorer database (distribution and threats); PNHP database (distribution); NYNHP Conservation Guides (background information); Fisheries and Oceans Canada 2009 (threats); Metcalfe-Smith et al. 2000 (threats); Metcalfe-Smith et al. 2003 (threats)
Lemmeria digitalis (Fingered lemmeria moth)	G4	S2S4	PS	VH		NatureServe 2008, Rawlins 2007. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Fingered Lemmeria Moth summary word document.
Lepus americanus (Snowshoe hare)	G5	S3S4	PS	High	Species range may shift and perhaps leave the assessment area.	Used the distribution/range map from NatureServe for range in PA since PNDI dataset has only 3 occurrences. This corresponds roughly with the Diefenbach (2010) distribution. (NatureServe 2010 and citations within) (Diefenbach 2010).

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Lycaena epixanthe (Bog copper)	G4G5	S2	HV	VH	Species range may shift and perhaps leave the assessment area.	Allen 1997, Glassberg 1999, Harper 2008, NatureServe Explorer, Opler 1992, Wright 2011. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Bog Copper summary word document.
Maianthemum trifolium (False Solomon's-seal)	G5	S4	HV	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Hossler 2010 (mycorrhizal association)
Margaritifera margaritifera (Eastern pearlshell)	G4	S1	EV	VH		NatureServe Explorer database (distribution and threats); Spoo 2008 (ecology, distribution); PNHP database (distribution); NYNHP Conservation Guides (background information); PA Bulletin, Doc#05-1675
Muhlenbergia uniflora (Fall dropseed muhly)	G5	S2	EV	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Hossler 2010 (mycorrhizal associations)
Myotis leibii (Eastern small-footed bat)	G3	S1B, S1N	MV	Low		Evaluated the distribution around the PNDI points and their supporting landforms. Checking "cave obligate" changes results from HV to PS (inappropriately); cave obligates should be exclusive cave obligates for the index to function correctly. Whidden 2010.

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Neotoma magister (Allegheny woodrat)	G3G4	S3	MV	High	Species may expand range in assessment area.	Distribution assessed was drawn to represent the occurrences tracked by the PGC and their supporting landforms. This area exceeds the PNDI distribution by including historical and potential sites. Hassinger et al. 1996. Merritt 1987. Wright, 2010, Hart pers. comm.
Oclemena nemoralis (Leafy bog aster)	G5	S1	EV	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Hossler 2010 (mycorrhizal associations)
Papaipema sp. 1 (Flypoison borer moth)	G2G3	S2	MV	VH		Butler 1998, NatureServe Explorer, Peacock et al. 1998, Rawlins 2007, Rhoads and Block 2000, Rhoads and Klein 1993. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Flypoison Borer Moth summary word document.
Paranga olivacea (Scarlet tanager)	G5	S5B	IL	VH		Atlas of Breeding Birds in PA (distribution, background information); McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats); Sauer et al., 2008 (background information)
Picea mariana (Black spruce)	G5	SNR	HV	Low		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Uchytil 1991 (background information)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Picea rubens (Red spruce)	G5	S4	EV	VH		Rhoads and Block 2007 (habitat description); Rhoads and Klein 1993 (distribution in PA); NatureServe 2011 (ranks); Sullivan 1993 (ecology, habitat, and seed dispersal); Govindaraju 1988 (dispersal distance)
Pieris virginiensis (West Virginia white)	G3?	S2S3	HV	VH		Allen 1997, Cappuccino and Kareiva 1985, Finnell and Lehn 2007, NatureServe Explorer 2008, Shortle et al. 2009. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the West Virginia White summary word document.
Platanthera blephariglottis (White fringed-orchid)	G4G5	S2S3	EV	VH		PNHP database and fact sheet; NatureServe Explorer; Jerakova and Malinova 2007 (dispersal); Machon et al. 2003 (dispersal); www.eol.org/pages/1134450 (pollinators)
Pleurobema clava (Clubshell)	G2	S1	HV	Mod		NatureServe Explorer database (distribution and threats); Spoo 2008 (ecology, distribution); PNHP database (distribution); NYNHP Conservation Guides (background information); US FWS 1994 (background information from recovery plan)
Prunus pumila var. depressa (Eastern sand cherry)	G5T5	S1	PS	Mod	Species range may shift and perhaps leave the assessment area.	PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Taylor 2006 (background information, seed dispersal)
Pseudacris brachyphona (Mountain chorus frog)	G5	S1	HV	High	Species may expand range in assessment area.	Assessed based on PNDI distribution except factor C2bi which also considered historic range. If C2bi uses only current distribution (GI) then overall rank is Highly Vulnerable. NatureServe 2010, Diez and Maret 2010, UCS 2008, Hulse et al. 2001)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Pyrgus wyandot (Appalachian grizzled skipper)	G1G2Q	S1	MV	Low	Species may expand range in assessment area.	Allen 1997, Butler 1998, NatureServe Explorer, Peacock et al. 1998, Schweitzer 1989. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Grizzled Skipper summary word document.
Quercus phellos (Willow oak)	G5	S2	MV	VH	Species may expand range in assessment area.	PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat)
Rhododendron canadense (Rhodora)	G5	SNR	HV	Low		Rhoads and Block 2007 (habitat and distribution); Rhoads and Klein 1993 (distribution); Largent et al. 1980 (mycorrhizal association); Campbell et al. 2003 (seed dispersal)
Rhododendron groenlandicum (Labrador-tea)	G5	S3	EV	VH		PNHP database; NatureServe Explorer; Rhoads and Block 2007; Gucker 2006 (ecology and seed dispersal)
Rhynchospora alba (White beak-rush)	G5	SNR	MV	Low		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Hossler 2010 (mycorrhizal associations)
Rotala ramosior (Toothcup)	G5	S3	PS	Mod		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Mattrick 2001 (background information, seed dispersal)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Ruellia strepens (Wild limestone petunia)	G4G5	S2	MV	VH	Species may expand range in assessment area.	PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat)
Salix petiolaris (Meadow willow)	G5	S4	PS	VH	Species range may shift and perhaps leave the assessment area.	PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Gage and Cooper 2005 (seed dispersal)
Scaphiopus holbrookii (Spadefoot toad)	G5	S1	EV	Low		
Scheuchzeria palustris (Pod-grass)	G5	S1	EV	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Tallis and Birks 1965 (background information)
Schoenoplectus subterminalis (Water bulrush)	G4G5	S3	MV	Low		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Hossler 2010 (mycorrhizal association); Williams 1990 (distribution); ODNR 1984 (background)
Seiurus motacilla (Louisiana waterthrush)	G5	S5B	IL	VH		Atlas of Breeding Birds in PA (distribution, background information); McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Speyeria idalia (Regal fritillary)	G3	S1	PS	VH		Glassberg, 1999, NatureServe Explorer 2008, Powell and Kindscher 2007, Rawlins 2007, Williams 2002. See also the INVERTS additional CCVI documentation spreadsheet and the Regal Fritillary summary word document.
Sphalloplana pricei (Refton cave planarian)	G2G3	S1	PS	VH		Byers and Norris 2011, Holsinger and Culver 1988, NatureServe Explorer 2008, NatureServe 2010, Thorp and Covich (eds) 1991. See also the INVERTS additional CCVI documentation spreadsheet and the Refton Cave Planarian summary word document.
Solidago uliginosa (Bog goldenrod)	G4G5	S3	PS	VH		PNHP database; Rhoads and Block 2007 (habitat and distribution)
Stygobromus stellmacki (Stellmack's cave amphipod)	G1G2	S1	PS	VH		Byers and Norris 2011, Holsinger 1978, NatureServe Explorer 2008, NatureServe 2010, Thorp and Covich (eds) 1991. See also the INVERTS additional CCVI documentation spreadsheet and the Stellmack's Cave Amphipod summary word document.
Sylvilagus obscurus (Appalachian cottontail)	G4	SU	PS	VH	Species may expand range in assessment area.	Distribution in PA was mapped by encompassing the EOs and including the major landforms that appear to harbor them and potential habitat. R. Barry Pers. Comm. UCS 2008.
Tipularia discolor (Cranefly orchid)	G4G5	S3	HV	VH		PNHP database (distribution); NatureServe Explorer; Rasmussen and Whigham 1993, 1998 (seed ecology); Rhoads and Klein 1993 (distribution); Whigham 1990, 2004 (growth and reproduction)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Utricularia cornuta (Horned bladderwort)	G5	S2	EV	VH		PNHP database; NatureServe Explorer, Encyclopedia of Life
Vaccinium macrocarpon (Cranberry)	G4	SNR	HV	VH		Rhoads and Block 2007 (habitat description); Rhoads and Klein 1993 (distribution in PA); NatureServe 2011 (ranks, global range, and threats); Largent et al. 1980 (mycorrhizal association)
Vaccinium oxycoccos (Small cranberry)	G5	SNR	HV	Mod		Rhoads and Block 2007 (habitat description); Rhoads and Klein 1993 (distribution in PA); NatureServe 2011 (ranks, global range, and threats); Largent et al. 1980 (mycorrhizal association)
Vermivora chrysoptera (Golden-winged warbler)	G4	S4B	IL	Mod		Atlas of Breeding Birds in PA (distribution, background information); McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats); Confer 1992 (background information)
Vermivora pinus (Blue-winged warbler)	G5	S4B	IL	VH		Atlas of Breeding Birds in PA (distribution, background information); McWilliams and Brauning 2000 (background information); NatureServe Explorer database (threats)
Villosa fabalis (Rayed bean)	G2	S1	HV	Mod		NatureServe Explorer database (distribution and threats); Spoo 2008 (ecology, distribution); PNHP database (distribution); NYNHP Conservation Guides (background information)

Species	G-Rank	S-Rank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Viola selkirkii (Great spurred violet)	G5?	S3	HV	VH		PNHP database (distribution); NatureServe Explorer (distribution); Rhoads and Klein 1993 (distribution); Rhoads and Block 2007 (habitat); Ohkawara and Higashi 1994 (dispersal); Hornbeck et al. 2003 (background information); Gleason and Cronquist 1991 (habitat); Britton and Brown 1970 (habitat)
Zale curema (Northeastern pine zale)	G3G4	S1	PS	Low		Butler 1998, NatureServe 2008, Schweitzer 1985, Shortle et al. 2009. See also the spreadsheet INVERTS additional CCVI documentation spreadsheet and the Northeastern Pine Zale summary word document.

Appendix 4. Exposure and geography risk factors. Species are scored on how a factor affects its vulnerability (GI-greatly increase, Inc-increase, SI-somewhat increase, N-neutral, SD-somewhat decrease, D-decrease, and U-unknown). Those factors contributing most to a species' vulnerability are highlighted in red. Yellow indicates a moderate contribution to vulnerability and green indicates that a factor provides resilience to climate change (less vulnerable to climate change).

Species	PA Range Relative to Global Range	Temp 5.1 F	Temp 4.5 F	Most Drying	Mod Drying	Least Drying	Cave	Sea Level	Nat Barriers	Anthro Barriers	CC Mitigation
Abies balsamea (Balsam fir)	Southern edge of range	75	25	5	95			N	Inc-SI	N	N
Alasmidonta heterdon (Dwarf wedgemussel)	Center of range	100			100			N	SI	N	SI
Ambystoma jeffersonianum (Jefferson salamander)	Center of range	82	18	48	52			N	SI	Inc	U
Ammodramus henslowii (Henslow's sparrow)	Center of range	100		80	20			N	N	N	N
Andromeda polifolia (Bog-rosemary)	Southern edge of range	88	12	7	93			N	Inc	N	N
Arceuthobium pusillum (Dwarf mistletoe)	Southern edge of range		100		100			N	Inc-SI	N	N
Bartonia paniculata (Screwstem)	Center of range	75	25	28	72			N	SI	N	N
Caecidotea kenki (an isopod)	Northern edge of range	100		50	50		X	N	Inc	N	SI-N
Calephelis borealis (Northern metalmark)	Northern edge of range	50	50	50	50			N	N	SI-N	SI-N-SD
Callophrys irus (Frosted elfin)	East/west edge of range	25	75	25	75			N	N	SI-N	SI-N-SD
Calycopis cecrops (Red-banded hairstreak)	Northern edge of range	10	90	50	50			N	N	N	SD
Carex limosa (Mud sedge)	Southern edge of range	80	20	60	40			N	GI-Inc	N	N
Carex oligosperma (Few-seeded sedge)	Southern edge of range	80	20	60	40			N	GI-Inc	N	N
Carex paupercula (Bog sedge)	Southern edge of range	45	55	30	70			N	GI-Inc	N	N
Chamaedaphne calyculata (Leatherleaf)	Center of range	75	25	10	90			N	N	N	N
Cicindela ancocisconensis (Appalachian tiger beetle)	Center of range	100		100				N	N	N	SI-N

Species	PA Range Relative to Global Range	Temp 5.1 F	Temp 4.5 F	Most Drying	Mod Drying	Least Drying	Cave	Sea Level	Nat Barriers	Anthro Barriers	CC Mitigation
Cicindela patruela (Northern barrens tiger beetle)	Center of range	100		25	75			N	N	N	N-SD
Clemmys guttata (Spotted turtle)	Center of range	53	47	49	51			N	N	Inc	U
Conoclinum coelestinum (Mistflower)	Northern edge of range	65	35	25	75			N	N	SI-N	N
Coptis trifolia (Goldthread)	Center of range	85	15	15	85			N	SI	N	N
Cornus canadensis (Bunchberry)	Southern edge of range	90	10	85	15			N	SI	N	N
Crotalus horridus (Timber rattlesnake)	Center of range	90	10	46	54			N	N	SI	U
Cryptobranchus alleganiensis (Eastern hellbender)	Center of range	93	7	83	14	3		N	GI	GI	U
Cygnus columbianus (Tundra swan)	Southern edge of range		100	10	90			N	N	N	N
Dalibarda repens (Dewdrop)	Center of range	90	10	85	15			N	SI	N	N
Dendroica cerulean (Cerulean warbler)	Center of range	90	10	70	30			N	N	N	SI
Epioblasma torulosa rangiana (Northern riffleshell)	East/west edge of range	100		10	90			N	N	Inc	SI
Eriophorum virginicum (Tawny cotton-grass)	Center of range	80	20	55	45			N	N	N	N
Erythornium albidum (White trout-lily)	Northern edge of range	88	12	75	25			N	SI	N	N
Galium latifolium (Purple bedstraw)	Northern edge of range	100		100				N	N	N	N
Gaultheria hispidula (Creeping snowberry)	Southern edge of range	92	8	40	60			N	Inc	N	N
Glyptemys insculpta (Wood turtle)	Center of range	78	22	51	49			N	N	Inc	U
Glyptemys muhlenbergii (Bog turtle)	Center of range	12.5	87.5	43	57			N	Inc	Inc	U
Gomphus quadricolor (Rapids clubtail)	Center of range	75	25	5	95			N	N	N	Inc

Species	PA Range Relative to Global Range	Temp 5.1 F	Temp 4.5 F	Most Drying	Mod Drying	Least Drying	Cave	Sea Level	Nat Barriers	Anthro Barriers	CC Mitigation
Helmitheros vermivorus (Worm-eating warbler)	Northern edge of range	90	10	80	20			N	N	N	SI
Hylocichla mustelina (Wood thrush)	East/west edge of range	80	20	55	45			N	N	N	SI
Juncus filiformis (Thread rush)	Southern edge of range	10	90	10	90			N	SI	N	N
Kalmia polifolia (Bog laurel)	Southern edge of range	55	45		100			N	Inc	N	N
Lampsilis cariosa (Yellow lampmussel)	Center of range	90	10	90	10			N	N	Inc	SI
Lemmeria digitalis (Fingered lemmeria moth)	Center of range	100		5	95			N	N	N	SI-N
Lepus americanus (Snowshoe hare)	Southern edge of range	93	7	47	53			N	N	SI-N	U
Lycaena epixanthe (Bog copper)	Southern edge of range	60	40	35	65			N	N	N	SI
Maianthemum trifolium (False Solomon's-seal)	Southern edge of range	57	43	3	97			N	Inc	N	N
Margaritifera margaritifera (Eastern pearlshell)	Southern edge of range	50	50		100			U	SI	GI	SI
Muhlenbergia uniflora (Fall dropseed muhly)	Southern edge of range	90	10	10	90			N	GI-Inc	N	N
Myotis leibii (Eastern small-footed bat)	Center of range	77.7	22.3	56	44			N	N	N	Inc
Neotoma magister (Allegheny woodrat)	Northern edge of range	90	10	46	54			N	Inc-SI	Inc-SI	U
Oclemena nemoralis (Leafy bog aster)	Southern edge of range	100		100				N	GI-Inc	N	SI-N

Species	**PA Range Relative to Global Range**	**Temp 5.1 F**	**Temp 4.5 F**	**Most Drying**	**Mod Drying**	**Least Drying**	**Cave**	**Sea Level**	**Nat Barriers**	**Anthro Barriers**	**CC Mitigation**
Papaipema sp. 1 (Flypoison borer moth)	Entire range	40	60	30	70			N	N	N	SI
Paranga olivacea (Scarlet tanager)	East/west edge of range	80	20	55	45			N	N	N	SI
Picea mariana (Black spruce)	Southern edge of range	54	46	93	7			N	Inc-SI	N	N
Picea rubens (Red spruce)	Center of range	65	35	10	90			N	SI	N	N
Pieris virginiensis (West Virginia white)	East/west edge of range	90	10	35	65			N	N	Inc	Inc
Platanthera blephariglottis (White fringed-orchid)	Southern edge of range	45	55		100			N	Inc	N	N
Pleurobema clava (Clubshell)	East/west edge of range	100		40	60			N	SI-N	Inc-SI	SI
Prunus pumila var. depressa (Eastern sand cherry)	Southern edge of range	70	30	14	86			N	SI-N	N	N
Pseudacris brachyphona (Mountain chorus frog)	Northern edge of range	100		100				N	N	Inc	U
Pyrgus wyandot (Appalachian grizzled skipper)	Northern edge of range	50	50	90	10			N	N	N	SI-N-SD
Quercus phellos (Willow oak)	Northern edge of range	88	12	75	25			N	N	Inc	N
Rhododendron canadense (Rhodora)	Southern edge of range	60	40	2	98			N	SI	N	N
Rhododendron groenlandicum (Labrador-tea)	Southern edge of range	40	60		100			N	Inc	N	N
Rhynchospora alba (White beak-rush)	Center of range	51	49	14	86			N	SI	N	N
Rotala ramosior (Toothcup)	Northern edge of range	18	82	55	45			N	SI	N	N
Ruellia strepens (Wild limestone petunia)	Northern edge of range	100		100				N	SI	N	N

Species	PA Range Relative to Global Range	Temp 5.1 F	Temp 4.5 F	Most Drying	Mod Drying	Least Drying	Cave	Sea Level	Nat Barriers	Anthro Barriers	CC Mitigation
Salix petiolaris (Meadow willow)	Southern edge of range	95	5	30	70			N	N	N	N
Scaphiopus holbrookii (Spadefoot toad)	Northern edge of range		100	60	40			N	Inc	Inc	U
Scheuchzeria palustris (Pod-grass)	Southern edge of range	75	25	25	75			N	Inc	N	N
Schoenoplectus subterminalis (Water bulrush)	Center of range	86	14	24	76			N	SI	N	N
Seiurus motacilla (Louisiana waterthrush)	East/west edge of range	80	20	55	45			N	N	N	SI
Speyeria idalia (Regal fritillary)	Center of range	50	50	50	50			N	N	N	N
Sphalloplana pricei (Refton cave planarian)	Entire range	50	50	60	40		X	N	Inc	N	N
Solidago uliginosa (Bog goldenrod)	Center of range	60	40	18	82			N	N	N	N
Stygobromus stellmacki (Stellmack's cave amphipod)	Entire range	100		95	5		X	N	Inc	N	N
Sylvilagus obscurus (Appalachian cottontail)	Northern edge of range	100		63	37			N	SI-N	N	U
Tipularia discolor (Cranefly orchid)	Northern edge of range	20	80	65	35			N	SI	SI	N
Utricularia cornuta (Horned bladderwort)	Center of range	82	18		100			N	GI	N	N
Vaccinium macrocarpon (Cranberry)	Center of range	75	25	15	85			N	SI	N	N
Vaccinium oxycossos (Small cranberry)	Center of range	80	20	5	95			N	Inc-SI	N	N
Vermivora chrysoptera (Golden-winged warbler)	Center of range	90	10	75	25			N	N	N	SI-N-SD
Vermivora pinus (Blue-winged warbler)	East/west edge of range	80	20	40	60			N	N	N	SI-N

Species	**PA Range Relative to Global Range**	**Temp 5.1 F**	**Temp 4.5 F**	**Most Drying**	**Mod Drying**	**Least Drying**	**Cave**	**Sea Level**	**Nat Barriers**	**Anthro Barriers**	**CC Mitigation**
Villosa fabalis (Rayed bean)	East/west edge of range	100		15	85			U	SI-N	Inc	SI
Viola selkirkii (Great spurred violet)	Southern edge of range	100		18	82			N	SI	N	N
Zale curema (Northeastern pine zale)	Center of range		100	5	95			N	N	Inc-SI	N

Appendix 5. Intrinsic and modeled risk factor scores. Species are scored on how a factor affects its vulnerability (GI-greatly increase, Inc-increase, SI-somewhat increase, N-neutral, SD-somewhat decrease, D-decrease, and U-unknown). Those factors contributing most to a species' vulnerability are highlighted in red. Yellow indicates a moderate contribution to vulnerability and green indicates that a factor provides resilience to climate change (less vulnerable to climate change).

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Abies balsamea (Balsam fir)	SI-N	N	GI	Inc	SI	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Alasmidonta heterdon (Dwarf wedgemussel)	SI	N	N	GI	N	SI	N	N	N	N	N/A	SI	N	U	U	U	U	U	U	U
Ambystoma jeffersonianum (Jefferson salamander)	SI-N	N	SI-N	N	Inc	N	N	SI-N	N	SI	N/A	N	N	U	U	U	U	U	U	U
Ammodramus henslowii (Henslow's sparrow)	Dec	N	N	SI	N	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U
Andromeda polifolia (Bog-rosemary)	SI	N	GI	SI	Inc	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Arceuthobium pusillum (Dwarf mistletoe)	N	N	GI	Inc	N	N	N	N	GI	N/A	N	N	N	U	U	U	U	U	U	U
Bartonia paniculata (Screwstem)	Inc	N	SI-N	N	SI-N	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Caecidotea kenki (an isopod)	SI	N	U	SI	U	N	N	SI	N	N	N/A	N	N	U	U	U	U	U	U	U
Calephelis borealis (Northern metalmark)	N	N	U	SI	U	SI-N-SD	N	SI	N	Inc	N/A	N	N	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Callophrys irus (Frosted elfin)	SD	N	U	SI	U	SI-N-SD	N	N	N	Inc	N/A	N	N	U	U	U	U	U	U	U
Calycopis cecrops (Red-banded hairstreak)	SD	N	U	SI	U	N	N	SD	N	SD	N/A	N	N	U	U	U	U	U	U	U
Carex limosa (Mud sedge)	SI	N	Inc	SI	SI	N	N	N	N	N/A	N	N	N	U	U	U	U	U	U	U
Carex oligosperma (Few-seeded sedge)	SI	N	GI	SI	Inc	N	N	N	N	N/A	N	N	U	U	U	U	U	U	U	U
Carex paupercula (Bog sedge)	N	N	GI-Inc	SI	GI-Inc	N	N	N	N	N/A	N	N	U	U	U	U	U	U	U	U
Chamaedaphne calyculata (Leatherleaf)	N	N	SI	SI	Inc	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Cicindela ancocisconensis (Appalachian tiger beetle)	SD	N	U	SI	U	SI	N	SI	SI	N	N/A	N	N	U	SI	U	U	U	U	U
Cicindela marginipennis (Cobblestone tiger beetle)	SD	N	U	N	U	SI	N	Inc-SI	N	N	N/A	N	N	U	SI	U	U	U	U	U
Cicindela patruela (Northern barrens tiger beetle)	SD	N	U	SI	U	SD	N	SI	N	N	N/A	N	N	U	U	U	U	U	U	U
Clemmys guttata (Spotted turtle)	SI-N	N	SI	SI	SI-N	N	N	N	N	SD	N/A	N	N	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Conoclinum coelestinum (Mistflower)	SI-N	N	N-SD	SI	N	N	N	N	N	N/A	N	N	N	U	U	U	U	U	U	U
Coptis trifolia (Goldthread)	Inc	N	Inc	N	SI	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Cornus canadensis (Bunchberry)	N-SD	N	Inc	SI	SI-N	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Crotalus horridus (Timber rattlesnake)	N-SD	N	SD	N	SI-N	N-SD	N	SI	N	N	N/A	N	N	U	U	U	U	U	U	U
Cryptobranchus alleganiensis (Eastern hellbender)	N-SD	N	SI	N	Inc-SI	N	N	SI	N	SI	N/A	N	N	Inc-SI	N/A	U	U	U	U	U
Cygnus columbianus (Tundra swan)	Dec	N	N	Inc	N-SD	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U
Dalibarda repens (Dewdrop)	Inc	N	Inc	SI	SI	N	N	N	N	N/A	N	N	SI-N	U	U	U	U	U	U	U
Dendroica cerulean (Cerulean warbler)	SD-Dec	N	N	SI	N	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U
Epioblasma torulosa rangiana (Northern riffleshell)	SI	N	N	Inc	N	SI-N	N	N	N	N	N/A	SI	N	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Eriophorum virginicum (Tawny cotton-grass)	N	N	N	N	Inc-SI	N	N	N	U	N/A	N	N	N	U	U	U	U	U	U	U
Erythornium albidum (White trout-lily)	SI	N	N	SI	N	N	N	SI	N	N/A	N	SI-N	U	U	U	U	U	U	U	U
Galium latifolium (Purple bedstraw)	SI	N	N	Inc	N	N	N	N	N	N/A	N	N	N	U	U	U	U	U	U	U
Gaultheria hispidula (Creeping snowberry)	N	N	GI	SI	SI	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Glyptemys insculpta (Wood turtle)	SD	N	N-SD	N	N	SI-N	N	SD	N	SD	N/A	N	N	U	U	U	U	U	U	U
Glyptemys muhlenbergii (Bog turtle)	SI-N	N	N-SD	SI	Inc	N	N	SI	SI-N	SD	N/A	N	N	U	U	U	U	U	U	U
Gomphus quadricolor (Rapids clubtail)	SD	N	SI	SI	SI	N	N	N	N	N	N/A	N	N	U	U	U	U	U	U	U
Gomphus viridifrons (Green-faced clubtail)	SD	N	SI	SI	SI	N	N	N	N	N	N/A	N	N	U	U	U	U	U	U	U
Helmitheros vermivorus (Worm-eating warbler)	Dec	N	N	SI	N	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Hylocichla mustelina (Wood thrush)	Dec	N	N	N	N	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U
Juncus filiformis (Thread rush)	N	N	Inc	SI	SI	N	N	N	N	N/A	N	N	N	U	U	U	U	U	U	U
Kalmia polifolia (Bog laurel)	SI	N	GI	Inc	Inc	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Lampsilis cariosa (Yellow lampmussel)	SI	N	N	SI	N	SI-N	N	N	N	N	N/A	SI	N	U	U	U	U	U	U	U
Lemmeria digitalis (Fingered lemmeria moth)	SD	N	U	Inc	SI	N	N	N	N	SI	N/A	N	N	U	U	U	U	U	U	U
Lepus americanus (Snowshoe hare)	Dec	N	N	SI-N	N	N-SD	SI	N	N	N	N/A	N	N	U	U	U	U	U	U	U
Lycaena epixanthe (Bog copper)	N	N	Inc	N	U	N	N	SI	SI	SI	N/A	N	N	U	U	U	U	U	U	U
Maianthemum trifolium (False Solomon's-seal)	N	N	GI	SI	GI-Inc	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Margaritifera margaritifera (Eastern pearlshell)	SI	N	GI	GI	N	SI	N	N	N	N	N/A	SI	N	U	U	U	U	U	U	U
Muhlenbergia uniflora (Fall dropseed muhly)	N	N	GI	Inc	Inc	N	N	N	N	N/A	U	N	SI	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Myotis leibii (Eastern small-footed bat)	SD-Dec	N	SI	N	SI-N	N	N	Inc	N	N	N/A	N	N	U	U	U	U	U	U	U
Neotoma magister (Allegheny woodrat)	SI-N	N	N	N	N	U	U	SI	N	N	N/A	N	N	U	U	U	U	U	U	U
Oclemena nemoralis (Leafy bog aster)	N	N	GI	GI	Inc	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Papaipema sp. 1 (Flypoison borer moth)	SD	N	U	SI	SI	SI	N	N	N	Inc	N/A	N	N	U	U	U	U	U	U	U
Paranga olivacea (Scarlet tanager)	Dec	N	N	N	N	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U
Picea mariana (Black spruce)	SI	N	GI	SI	SI	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Picea rubens (Red spruce)	SI	N	GI	SI	SI	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Pieris virginiensis (West Virginia white)	SD	N	Inc	N	U	N	N	N	N	SI	N/A	N	N	U	U	U	U	U	U	U
Platanthera blephariglottis (White fringed-orchid)	SI	N	GI	SI	GI-Inc	N	N	N	GI	N/A	N	U	SI	U	U	U	U	U	U	U
Pleurobema clava (Clubshell)	SI-N	N	N	SI	N	SI	N	N	N	N	N/A	SI	N	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other spp	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Prunus pumila var. depressa (Eastern sand cherry)	N-SD	N	N	Inc	N	N	SI	SI	N	N/A	N	N	N	U	U	U	U	U	U	U
Pseudacris brachyphona (Mountain chorus frog)	SI-N	N	U	GI-Inc-SI	Inc	N	N	SD	N	N	N/A	N	N	U	Inc	U	U	U	U	U
Pyrgus wyandot (Appalachian grizzled skipper)	SD	N	SI-N-SD	SI	U	SI-N-SD	N	Inc	N	Inc	N/A	N	N	U	U	U	U	U	U	U
Quercus phellos (Willow oak)	N	N	SD	Inc	SI	N	N	SI	N	N/A	N	N	N	U	U	U	U	U	U	U
Rhododendron canadense (Rhodora)	SI	N	GI	SI	SI-N	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Rhododendron groenlandicum (Labrador-tea)	Inc	N	GI	Inc	Inc	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Rhynchospora alba (White beak-rush)	SI-N	N	SI	N	Inc-SI	N	N	N	N	N/A	N	N	SI-N	U	U	U	U	U	U	U
Rotala ramosior (Toothcup)	N	N	N-SD	Inc	SI-N	N	N	N	N	N/A	N	N	N	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other spp	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Ruellia strepens (Wild limestone petunia)	N	N	N	Inc	N	N	N	SI	N	N/A	N	N	N	U	U	U	U	U	U	U
Salix petiolaris (Meadow willow)	N	SI	N	N	SI-N	N	N	N	N	N/A	N	N	N	U	U	U	U	U	U	U
Scaphiopus holbrookii (Spadefoot toad)	Inc-SI	N	N	GI-Inc	SI-N	N	N	SI	N	N	N/A	N	N	U	U	U	U	U	U	U
Scheuchzeria palustris (Pod-grass)	Inc	N	GI-Inc	Inc	Inc	N	N	N	N	N/A	N	U	U	U	U	U	U	U	U	U
Schoenoplectus subterminalis (Water bulrush)	SI-N	N	N	Inc	SI-N	N	N	N	N	N/A	U	N	SI-N	U	U	U	U	U	U	U
Seiurus motacilla (Louisiana waterthrush)	Dec	N	N	N	N	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U
Speyeria idalia (Regal fritillary)	SD	N	U	N	U	SD	N	N	N	SI	N/A	N	N	U	U	U	U	U	U	U
Sphalloplana pricei (Refton cave planarian)	Inc	N	U	SI	U	N	N	Inc	N	N	N/A	N	N	U	U	U	U	U	U	U
Solidago uliginosa (Bog goldenrod)	N	N	SI-N	SI	SI	N	N	N	N	N/A	N	N	N	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other spp	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Stygobromus stellmacki (Stellmack's cave amphipod)	Inc	N	U	SI	U	N	N	Inc	N	N	N/A	N	N	U	U	U	U	U	U	U
Sylvilagus obscurus (Appalachian cottontail)	SD-Dec	N	SI-N	N	N	N-SD	N	N	N	N	N/A	N	N	U	U	U	U	U	U	U
Tipularia discolor (Cranefly orchid)	SI	N	N	Inc	N	N	N	N	GI	N/A	N	N	SI	U	U	U	U	U	U	U
Utricularia cornuta (Horned bladderwort)	Inc-SI	N	GI	Inc	GI	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Vaccinium macrocarpon (Cranberry)	N	N	Inc	SI	SI	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Vaccinium oxycossos (Small cranberry)	SI-N	N	Inc	SI	GI	N	N	N	N	N/A	N	N	SI	U	U	U	U	U	U	U
Vermivora chrysoptera (Golden-winged warbler)	Dec	N	N	SI	N	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U

Species	Dispersal/ movement	Hist therm niche	Physio therm niche	Hist hydro niche	Physio hydro niche	Disturbance	Ice/snow	Physical habitat	Other spp for habitat	Diet	Pollinators	Other spp for dispersal	Interaction with other spp	Genetic variation	Genetic bottleneck	Phenological response	Doc response	Modeled change	Modeled overlap	Protected areas
Vermivora pinus (Blue-winged warbler)	Dec	N	N	N	N	N	N	SD	N	N	N/A	N	N	U	U	U	U	U	U	U
Villosa fabalis (Rayed bean)	SI	N	N	Inc	N	SI-N	N	N	N	N	N/A	SI	N	U	U	U	U	U	U	U
Viola selkirkii (Great spurred violet)	Inc	N	GI	SI	N	N	N	N	N	N/A	N	N	N	U	U	U	U	U	U	U
Zale curema (Northeastern pine zale)	SD	N	U	Inc	U	SD	N	SI	N	Inc	N/A	N	N	U	U	U	U	U	U	U

Appendix 6. Summary of CCVI results for each species organized by taxonomic group.

AMPHIBIANS

Species: Eastern Hellbender (*Cryptobranchus a. alleganiensis*)
Global Rank: G3G4
State Rank: S3
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Extremely Vulnerable
Confidence: Very High

<u>Habitat:</u>

Eastern hellbender is found in medium and large streams, with a preference for cold, shallow, moderate to fast-flowing water and areas with gravel and sandy substrate and an abundance of large flat rock slabs (Hulse et al. 2001). The range of the species extends from southern New York south to northern Georgia and west to Missouri (NatureServe 2010).

<u>Current Threats:</u>

Principle threats to the species are degradation of habitat and overexploitation by collection and illegal or unintentional harvest (NatureServe 2010). Hellbenders appear to be intolerant of heavy recreational use of the habitat.

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to natural topographic or geographic habitat barriers: Eastern hellbenders are an aquatic stream species and as such, are limited in their ability to move with changing climate conditions only within their currently occupied watersheds.

Distribution relative to anthropogenic barriers: The presence of dams on rivers where eastern hellbenders are found would make movement in response in climate change very difficult.

Predicted micro sensitivity to changes in temperature: The species is dependent on streams towards the cooler end of the temperature spectrum.

Physical habitat specificity: The species is moderately to highly specialized in its physical habitat requirements. As adults, eastern hellbenders require stream bottoms with boulders and large, flat rocks (Hulse et al. 2001).

Dietary versatility: Eastern hellbenders are not versatile in their dietary requirements. Adults eat a diet of mainly crayfish (although small fish and invertebrates may be taken opportunistically) (Hulse et al. 2001).

Measured genetic variation: There is little genetic variation across the entire range of the species (Routman 1993; Routman et al. 1994).

References:

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Routman, E. 1993. Mitochondrial DNA variation in *Cryptobranchus alleganiensis*, a salamander with extremely low allozyme diversity. Copeia 1993:407-416.

Routman, E., R.Wu, and A.R. Templeton. 1994. Parsimony, molecular evolution, and biogeography: the case of the North American giant salamander. Evolution 48:1799-1809.

Species: Eastern Spadefoot (*Scaphiopus holbrookii*)
Global Rank: G5
State Rank: S1/S2
State Wildlife Action Plan: High-level Concern Species
Climate Change Vulnerability: Extremely Vulnerable
Confidence: Low

Habitat:

The unpredictable and primarily fossorial nature of the eastern spadefoot makes it a difficult species to study. In Pennsylvania, the eastern spadefoot usually inhabits sandy soils along the floodplains of streams and rivers and in agricultural fields (Hulse et al. 2001). Seasonal activity is variable and dependent upon the frequency and intensity of rainfall (Hulse et al. 2001). A heavy rain event usually preceeds breeding which occurs in vernal pools (Gibbs et al. 2007). The species can be found from Cape Cod to the Florida Keys and west to eastern Missouri and Louisiana (White and White 2002).

Current Threats:

Current threats to the species include habitat destruction from development, habitat alteration, and changes in water chemistry from agricultural practices.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Upland habitat and mountains to the north of the species current known range in Pennsylvania may likely limit its ability to move northward in response to climate change.

Distribution relative to anthropogenic barriers: Major highways in Pennsylvania, such as the Pennsylvania Turnpike, create dangerous obstacles for northern movement of the eastern spadefoot.

Predicted impact of land use changes resulting for human responses to climate change: Climate change mitigation activities, such as the construction of solar facilities, may occur within the current range or potential future range of the species.

Dispersal and movements: Evidence suggests that the eastern spadefoot is probably only capable of short distance dispersal. Based on observations of a Florida population, Pearson reported an average home range of about $12m^2$ (Pearson 1955).

Predicted sensitivity to exposure to past variations in precipitation: Considering the species range in Pennsylvania, the eastern spadefoot has experienced a very small variation in precipitation in the past fifty years.

Predicted sensitivity to changes in physiological hydrological niche: The species is completely dependent on vernal pools for egg laying and the larval stage. The hydrology of these systems may be altered due to changes in precipitation patterns and increased temperatures. An alteration in the pattern of heavy rain events and the seasonality at which they occur may also impact this species since explosive breeding events usually follow heavy rainstorms.

References:

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Pearson, P.G. 1955. Population ecology of the spadefoot toad, *Scaphiopus h. holbrooki* (Harlan). Ecological Monographs 25: 233-267.

White Jr, J.F. and A.W. White. 2002. Amphibians and Reptiles of Delmarva. Tidewater Publishers, Centreville, Maryland. pp 73-75.

Species: Jefferson Salamander (*Ambystoma jeffersonianum*)
Global Rank: G4
State Rank: S3S4
State Wildlife Action Plan: Responsibility Species
Climate Change Vulnerability: Highly Vulnerable
Confidence: Low

Habitat:

Jefferson salamander is found in well-drained deciduous or mixed upland forests within 250 to 1600 m of a small vernal pool or pond (MA NHESP 2007). Within the United States, the species range extends from southern New York, northern New Jersey, and most of Pennsylvania to Ohio and southern Indiana. Their range extends southward to Kentucky, West Virginia, and Virginia (NatureServe 2010).

Current Threats:

Current threats to the species include alteration of vernal pool breeding sites, loss and alteration of forested habitats surrounding pools, road mortality during migration to and from breeding sites, and acidification of vernal pools due to acid deposition (NatureServe 2010).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: The species is found in and around vernal pools (depending on season and life stage). Natural barriers such as extensive forests between pools will make movement for this species very difficult.

Distribution relative to anthropogenic barriers: Significant areas of urban development and agriculture occur within the species range in Pennsylvania that would impair movement in response to climate change.

Dispersal and movements: Young tend to move less than 100 m/yr during the dispersal process (Douglas and Monroe 1981; Semlitsch 2007).

Predicted micro sensitivity to changes in temperature: Jefferson salamanders prefer moist and cool microhabitats.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Jefferson salamanders are completely dependent on aquatic habitats (vernal pools or small ponds) for egg laying and the larval stage. The hydrology of these systems may be altered due to climate change effects.

Physical habitat specificity: The species is moderately to highly specialized in its physical requirements for vernal pools. A specific water chemistry range (a function of surrounding soils and underlying bedrock) is required within pools for successful larval growth (Freda and Dunson 1986).

Dietary versatility: While adults eat a wide range of invertebrate prey, larvae are largely limited to a diet dependent on anuran larvae and aquatic invertebrates that also reproduce in seasonal pools.

References:

Douglas, M.E., and B.L. Monroe, Jr. 1981. A comparative study of topographical orientation in Ambystoma (Amphibia: Caudata). Copeia 1981:460-463.

Freda, J. and W.A. Dunsin. 1986. Effects of low pH and other chemical variables on the local distribution of amphibians. Copeia 1986:454-466.

Massachusetts Natural Heritage Endangered Species Program. 2007. MA NHESP Fact Sheet – Jefferson Salamander (accessed 3/2010).

NatureServe. 2010. NatureServe central Databases. Arlington, Virginia. USA.

Semlitsch, R. 2007. Differentiating migration and dispersal processes of pond-breeding amphibians. Journal of Wildlife Management 72:260-267.

Species: Mountain Chorus Frog (*Pseudacris brachyphona*)
Global Rank: G5
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Very High

<u>Habitat:</u>

Mountain chorus frog is a terrestrial species found in deciduous woodlands and upland wooded areas that requires small bodies of water for egg laying and larval metamorphosis. The species is discontinuously distributed from western Pennsylvania southwest to northeastern Mississippi, central Alabama, and Georgia (NatureServe 2010).

<u>Current Threats:</u>

Threats to this species include loss and alteration of habitat, loss of breeding wetlands, and acidification of breeding pools by acid deposition (NatureServe 2010).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to anthropogenic barriers: Urban and agricultural land surrounding the current distribution of known occurrences in Pennsylvania will likely prevent northward movement of the species in response to climate change.

Dispersal and movements: The young frogs probably do not disperse distances of more than 100 m/yr.

Predicted macro sensitivity to changes in temperature: Within the species range in Pennsylvania, mountain chorus frogs have experienced a very small temperature variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Mountain chorus frogs are completely dependent on aquatic habitats (e.g., vernal pools, ditches, small ponds) for egg laying and the larval stage. The hydrology of these systems may be altered due to climate change effects.

Occurrences of bottlenecks in recent evolutionary history: Given the extreme change in distribution over the past few decades (Hulse et al 2001), bottlenecks are assumed to have occurred for this species. PHNP data indicate that the occupied area was drastically reduced in the past 500 years.

References:

Diez, T. and T. J. Maret. 2010, Mountain Chorus Frog . In: Terrestrial Vertebrates of Pennsylvania: a complete guide to species of special concern. Edited by M. A. Steele, M. C.Brittingham, T. J. Maret, and J. F. Merritt. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Hulse, A.C., C.J. McCoy, and E. Censky. 2001. Amphibians and reptiles of Pennsylvania and the Northeast. Comstock Publishing Associates. Cornell University Press, Ithaca. 419 pp.

NatureServe. 2010. NatureServe central Databases. Arlington, Virginia. USA.

BIRDS

Species: Cerulean Warbler (*Dendroica cerulean*)
Global Rank: G4
State Rank: S4B
State Wildlife Action Plan: High-level Concern Species
Climate Change Vulnerability Index: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

Cerulean warblers are found throughout PA during migration and breed across the state, but are most common in the southwest (McWilliams and Brauning 2000). Cerulean warblers are usually found in mature, unfragmented stands in bottomlands or floodplains and also in oak forests at higher elevations along the mountain ridges (Brauning 1992; McWilliams and Brauning 2000).

Current Threats:

These birds prefer relatively unfragmented forest blocks with average size increasing to the south in its U.S. range. Deforestation of its wintering range in South America (east slope of Andes) may be most crucial but forest fragmentation in its breeding range in the U.S. and southern Canada may make it subject to predation and nest parasitism (NatureServe 2010).

Main Factors Contributing to Vulnerability Rank:

Although cerulean warblers may be sensitive to certain climate change related factors addressed in the CCVI, such as predicted land use impacts designed to mitigate against climate change, the CCVI rank is Not Vulnerable/Presumed Stable. Available evidence assessed in the CCVI suggests that abundance and/or range extent within Pennsylvania will not likely change (increase/decrease) substantially by 2050, but actual range boundaries may change. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related actions.

References:

Brauning, D.W. 1992. Atlas of Breeding Birds in Pennsylvania. University of Pittsburgh Press. Pittsburgh, PA, 484pp.

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Worm-eating Warbler (*Helmitheros vermivorus*)
Global Rank: G5
State Rank: S4B
State Wildlife Action Plan: Responsibility Species
Climate Change Vulnerability Index: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

Worm-eating warblers breed mostly east of the Allegheny Front (Ridge and Valley, Piedmont and Blue Ridge provinces) in wooded hillsides with dense understory (rhododendron, mountain laurel) and sometimes wet lowlands with dense shrub cover McWilliams and Brauning 2000).

Current Threats:

Worm-eating warblers are among the species most sensitive to forest fragmentation (McWilliams and Brauning 2000). Destruction of wintering habitat in the West Indies and Central America is also a threat to the species (Brauning 1992).

Main Factors Contributing to Vulnerability Rank:

Although the worm-eating warbler may be sensitive to certain climate change related factors addressed in the CCVI, such as predicted land use impacts designed to mitigate against climate change, the CCVI rank is Not Vulnerable/Presumed Stable. Available evidence does not suggest that abundance and/or range extent within Pennsylvania will change (increase/decrease) substantially by 2050, but actual range boundaries may change. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related actions.

References:

Brauning, D.W. 1992. Atlas of Breeding Birds in Pennsylvania. University of Pittsburgh Press. Pittsburgh, PA, 484pp.

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

Species: Golden-winged Warbler (*Vermivora chrysoptera*)
Global Rank: G4
State Rank: S4B
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability Index: Not Vulnerable/Increase Likely
Confidence: Moderate

Habitat:

Golden-winged warblers typically breed in shrubby, early successional habitats such as overgrown farmland, power cuts, and open swampy forests. They may also be found in areas of regrowth after timber cuts and forests damaged by gypsy moths (Brauning 1992; McWilliams and Brauning 2000).

Current Threats:

Population declines have been attributed to competition and hybridization between blue-winged warblers, nest parasitism by brown-headed cowbirds, reforestation of previously cleared lands, and conversion of early-successional habitats to development (McWilliams and Brauning 2000; NatureServe 2010). Loss of wintering habitat is also listed as a reason for species decline (Confer 1992).

Main Factors Contributing to Vulnerability Rank:

It is uncertain how golden-winged warblers may respond to predicted land use impacts designed to mitigate against climate change since some activities could potentially benefit the species by creating early successional habitat while other activities may harm the species (e.g., incidental death caused by wind turbines). However, despite the uncertainty of climate change mitigation effects, the CCVI rank is Not Vulnerable/Increase Likely. Available evidence suggests that abundance and/or range extent within Pennsylvania is likely to increase by 2050. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related actions.

References:

Brauning, D.W. 1992. Atlas of Breeding Birds in Pennsylvania. University of Pittsburgh Press, Pittsburgh, PA.

Confer, J.L. 1992. Golden-winged Warbler (*Vermivora chrysoptera*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from The Birds of North America Online: http://bna.birds.cornell.edu/bna/species/020.

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Henslow's Sparrow (*Ammodramus henslowii*)
Global Rank: G4
State Rank: S4
State Wildlife Action Plan: High-level Concern Species
Climate Change Vulnerability: Not Vulnerable/ Increase Likely
Confidence: Very High

Habitat:

Henslow's sparrow prefers extensive grasslands with some vertical structure for perching. The species may be found in meadows, uncut hayfields, and abandoned farm fields but is most commonly found in reclaimed mine sites (McWilliams and Brauning 2000).

Current Threats:

Henslow's sparrows are threatened by habitat loss and habitat fragmentation. The grassland habitat favored by Henslow's sparrows has been reduced due to urbanization, establishment of woody species resulting in a successional conversion from grassland into shrubland or forest, and conversion into agricultural lands. Fragmentation of suitable habitat into smaller patches is another serious threat (NatureServe 2010). Henslow's sparrows prefer generally open landscapes larger than 80 acres and avoid fields that were mowed the previous year (McWilliams and Brauning 2000).

Main Factors Contributing to Vulnerability Rank:

The CCVI rank for this species is Not Vulnerable/Increase Likely. Available evidence suggests that abundance and/or range extent within Pennsylvania is likely to increase by 2050. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related actions.

References:

Brauning, D.W. 1992. Atlas of Breeding Birds in Pennsylvania. University of Pittsburgh Press, Pittsburgh, PA.

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Tundra Swan (*Cygnus columbianus*)
Global Rank: G5
State Rank: S3
State Wildlife Action Plan: Responsibility Species
Climate Change Vulnerability Index: Not Vulnerable/Increase Likely
Confidence: Low

Habitat:

During migrations, tundra swans use lakes, sloughs, rivers, and sometimes fields. During the breeding season, they use open tundra, marshy lakes and ponds, and sluggish streams. During the winter, tundra swans occupy shallow lakes, ponds, and estuaries (NatureServe 2010).

Current Threats:

No trends seen in Canadian data (Collins and Downes 2009).

Main Factors Contributing to Vulnerability Rank:

The CCVI rank for this species is Not Vulnerable/Increase Likely. Available evidence suggests that abundance and/or range extent within Pennsylvania is likely to increase by 2050. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related actions.

References:

Collins, B.T. and C.M. Downes. 2009. Canadian Bird Trends Web site Version 2.3. Canadian Wildlife Service, Environment Canada, Gatineau, Quebec, K1A 0H3. Accessed 1/21/10

Earnst, S.L. and T.C. Rothe. 2004. Habitat selection by Tundra Swans on Northern Alaska breeding grounds. Water Birds 27(2): 224-233.

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Blue-winged Warbler (*Vermivora pinus*)
Global Rank: G5
State Rank: S4B
State Wildlife Action Plan: Responsibility Species
CCVI Rank: Not Vulnerable/Increase Likely
Confidence: Very high

<u>Habitat:</u>

Blue-winged warblers are found in overgrown fields, power-line cuts, open brushy second-growth woodlands or woodland edges, thickets, and shrubby swamps (McWilliams and Brauning 2000).

<u>Current Threats:</u>

Blue-winged warblers are sensitive to nest predation by brown-headed cowbirds (NatureServe 2010).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Although blue-winged warblers may be sensitive to certain climate change related factors addressed in the CCVI, such as predicted land use impacts designed to mitigate against climate change, the CCVI rank is Not Vulnerable/Increase Likely. Available evidence assessed in the CCVI suggests that abundance and/or range extent within Pennsylvania is likely to increase by 2050. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related actions.

<u>References:</u>

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Wood Thrush (*Hylocichla mustelina*)
Global Rank: G5
State Rank: S5B
State Wildlife Action Plan: Responsibility Species
Climate Change Vulnerability Index: Not Vulnerable/Increase Likely
Confidence: Very High

<u>Habitat:</u>

Wood thrush is a fairly common breeder in Pennsylvania. In the breeding season, the species prefers moist woodlands but will also use a variety of habitats, including dry hillsides, parks, orchards, and woodlots in suburbs (McWilliams and Brauning 2000). It prefers larger forested areas to smaller woodlots. During migration, wood thrushes are found in mixed woodlands and brushy edges (McWilliams and Brauning 2000).

<u>Current Threats:</u>

Although breeding bird data in eastern North America shows a slight population decline, wood thrushes are still abundant and occupy a large breeding range in eastern North America. The species is threatened by forest fragmentation and the resulting increases in nest predation (NatureServe 2010).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Although wood thrushes may be sensitive to certain climate change related factors addressed in the CCVI, the CCVI rank is Not Vulnerable/Increase Likely. Available evidence suggests that abundance and/or range extent within Pennsylvania is likely to increase by 2050. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related actions.

<u>References:</u>

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Scarlet Tanager (*Paranga olivacea*)
Global Rank: G5
State Rank: S5
State Wildlife Action Plan: Responsibility Species
Climate Change Vulnerability Index: Not Vulnerable/Increase Likely
Confidence: Very High

Habitat:

Scarlet tanagers are found in almost any mature woodlands, including pine stands (McWilliams and Brauning 2000).

Current Threats:

The greatest threat across the species' range is the continual loss and fragmentation of breeding and wintering habitat (NatureServe 2010). The Breeding Bird Survey reports a slight, but non-significant, loss between 1966 and 2007 throughout the species' range and within Pennsylvania (Sauer et al., 2008).

Main Factors Contributing to Vulnerability (as indicated by the CCVI):

Although scarlet tanagers may be sensitive to certain climate change related factors addressed in the CCVI, such as predicted land use impacts designed to mitigate against climate change, the CCVI rank is Not Vulnerable/Increase Likely. Available evidence assessed in the CCVI suggests that abundance and/or range extent within Pennsylvania is likely to increase by 2050. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD.

Species: Louisiana Waterthrush (*Seiurus motacilla*)
Global Rank: G5
State Rank: S5B
State Wildlife Action Plan: Responsibility Species
Climate Change Vulnerability Index: Not Vulnerable/Likely Increase
Confidence: Very High

Habitat:

The Louisiana waterthrush is found in the riparian zones of streams in unfragmented, forested watersheds (McWilliams and Brauning 2000).

Current Threats:

Potential threats include forest fragmentation and activities that cause reductions in forest canopy cover or negatively impact aquatic insect communities (Louisiana waterthrushes rely on aquatic macroinvertebrates as a food source). Reduced water quality of streams due to acid mine drainage and other forms of pollution can reduce food availability for the species (NatureServe 2010).

Main Factors Contributing to Vulnerability Rank:

Although the Louisiana watherthrush may be sensitive to certain climate change related factors addressed in the CCVI, the CCVI rank is Not Vulnerable/Likely Increase. Available evidence suggests that abundance and/or range extent within Pennsylvania is likely to increase by 2050. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related actions.

References:

McWilliams, G.M. and D.W. Brauning. 2000. The Birds of Pennsylvania. Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

CAVE INVERTEBRATES

Species: Stellmack's Cave Amphipod (*Stygobromus stellmacki*)
Global Rank: G1G2
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Very High

<u>Habitat (adapted from NatureServe 2008):</u>

Stellmack's cave amphipod is a stygobitic species (restricted to subterranean groundwater habitats) endemic to three cave systems in central Pennsylvania. Current limited survey information indicates that it inhabits three aquifers with one collection point for each watershed. The extent of this crustacean's distribution within these aquifers is unknown, though the species is not expected have a much expanded range. Stellmack's cave amphipod utilizes small streams, pools, and springs associated with limestone solution caves (Holsinger 1978). Adults and immatures are detritivores and scavengers, probably feeding upon bacteria, detritus, and carrion (Thorp and Covich 1991). Seasonality of this species' behavior or life-cycle may be based upon slight water temperature fluctuations.

<u>Current Threats (adapted from NatureServe 2008):</u>

This species is stygobitic and highly specialized to limestone caves within a small region of central PA. It is unlikely that many new sites will be discovered. The region where these populations are located is experiencing rapid agricultural, urban, and industrial growth. Protecting the groundwater is the key ingredient to long term viability of these populations. Potential threats to groundwater quality and quantity include pollution by agricultural fertilizers and pesticides, siltation, pumping of water from the aquifer for domestic and industrial uses, and industrial chemical spills. Upslope of the aquifers some potential exists for pollution from forestry practices and capture of surface run-off which might limit water reaching subterranean habitats. Limestone mining near the caves and/or aquifers would also be a serious threat.

<u>Main factors Contributing to Vulnerability:</u>

The key factors found to increase the vulnerability of Stellmack's cave amphipod to climate change are minimal ability to disperse outside of occupied cave systems, highly restricted range, specialized limestone cave habitat, increased groundwater demand and surface water capture expected due to increased frequency and duration of summer droughts. This cold-water amphipod is likely sensitive to changes in the seasonal hydrology and temperatures of the aquifer. However, a groundwater system should be able to moderate climatic changes to some degree.

In the CCVI version 2.0, obligate cave species were automatically given a higher resistance rating to climate change impacts. According to the CCVI guidelines (NatureServe 2010) and the West Virginia Climate Change Vulnerability Assessment Report (Byers and Norris 2011), cave species are expected to better survive climate changes in their buffered underground habitats.

Protecting water quality and quantity in occupied watersheds by increasing forest cover, prohibiting mining activities, implementing best management practices for agriculture, and limiting the addition of impervious surfaces and further water withdrawal or storage can provide important protection against current and future threats.

References:

Byers, E. and S. Norris. 2011. Climate Change Vulnerability Assessment of Species of Concern in West Virginia. West Virginia Division of Natural Resources, Elkins, WV.

Holsinger, J.R., 1978. Systematics of the subterranean amphipod genus *Stygobromus* (Crangonyctidae), Part II: Species of the eastern United States. Smithsonian Contributions to Zoology 266:1-144.

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: July 17, 2008)

NatureServe. 2010. Guidelines for Using the Climate Change Vulnerability Index, release 2.0, 27April2010. NatureServe, Arlington, Virginia.

Thorp, J.H. and A.P. Covich (eds). 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., Boston, MA. 911pp.

Species: Refton Cave Planarian (*Sphalloplana pricei*)
Global Rank: G2G3
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

The Refton cave planarian is a freshwater free-living Turbellaria in the "higher" taxonomic order Tricladida. Triclads are typically restricted geographically and have adaptations which allow them to utilize habitats with unusual conditions when compared to a typical stream or pond. Triclads are predators, hunting other invertebrates for food and scavenging upon injured or recently dead organisms. Turbellarian abundance will fluctuate according to seasonal succession (Thorp and Covich 1999).

Refton cave planarian inhabits the dark zone of caves, in drip or stream fed pools, or on the flat surfaces of rocks in small streams (Holsinger 1988). They may also be found underwater on rotting wood. Limited survey information has documented the Refton cave planarian at three cave sites in Pennsylvania, though it has not been seen since the 1930s at two of the three sites (NatureServe 2008). The extent of this flatworm's distribution within occupied aquifers is unknown, though the species is not expected have a much expanded range.

Current Threats (adapted from NatureServe 2008):

This species is stygobitic and is restricted to caves within a small region of southcentral Pennsylvania. It is unlikely that many new sites will be discovered. The region surrounding the only known extant population of Refton cave planarian has experienced rapid agricultural, urban, and industrial growth. Protecting the groundwater is the key ingredient to long term viability of any extant population. Potential threats to groundwater quality and quantity include pollution by agricultural fertilizers and pesticides, siltation, pumping of water from the aquifer for domestic and industrial uses, and industrial chemical spills. Upslope of the aquifers some potential exists for pollution from forestry practices and capture of surface run-off which might limit water reaching subterranean habitats. Limestone mining near occupied caves and/or aquifers would also be a serious threat.

Main factors Contributing to Vulnerability:

The key factors found to increase the vulnerability of the Refton cave planarian to climate change are minimal ability to disperse outside of occupied cave systems, highly restricted range, specialized cave habitat, increased groundwater demand and surface water capture expected due to increased frequency and duration of summer droughts. This cold-water planarian is likely sensitive to changes in the seasonal hydrology and temperatures of the aquifer. However, a groundwater system should be able to moderate climatic changes to some degree.

In the CCVI version 2.0, obligate cave species were automatically given a higher resistance rating to climate change impacts. According to the CCVI guidelines (NatureServe 2010) and the West Virginia Climate Change Vulnerability Assessment Report (Byers and Norris 2011), cave species are expected to better survive climate changes in their buffered underground habitats.

Protecting water quality and quantity in occupied watersheds by increasing forest cover, prohibiting mining activities, implementing best management practices for agriculture, and limiting the addition of impervious surfaces and further water withdrawal or storage can provide important protection against current and future threats.

References:

Byers, E. and S. Norris. 2011. Climate Change Vulnerability Assessment of Species of Concern in West Virginia. West Virginia Division of Natural Resources, Elkins, WV.

Holsinger, J.R. and D.C. Culver. 1988. The invertebrate cave fauna of Virginia and a part of eastern Tennessee: zoogeography and ecology. Brimleyana, 14:1-162.

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: July 17, 2008)

NatureServe. 2010. Guidelines for Using the Climate Change Vulnerability Index, release 2.0, 27April2010. NatureServe, Arlington, Virginia.

Thorp, J.H. and A.P. Covich (eds). 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., Boston, MA. 911pp.

Species: An isopod (*Caecidotea kenki*)
Global Rank: G3
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

Caecidotea kenki is apparently intermediate between an epigean (surface dwelling) and troglobotic (cave dwelling) species. Current limited survey information indicates that it inhabits four aquifers in Pennsylvania with one collection point for three watersheds and three points for the fourth. Across its entire known range, it has been documented from 17 sites historically (1933-1966). It has also been documented in Maryland, Virginia, and the District of Columbia. It is probably more widespread than records show and the number of sites could reasonably double with more survey effort (NatureServe 2008).

Caecidotea kenki possess tiny eyes and have pigmentation. While found in caves, they are primarily found in springs and spring-fed streams. Hutchins and Culver (2007) call this species a specialist of superficial groundwater sites, namely springs and seeps. They note that virtually nothing is known about the biology of the species. Crustaceans of cool-water habitats tend to have tight temperature requirements. Water temperature affects growth and metabolism rates, and temperature changes can impact species behaviors including competition and breeding (Thorp and Covich, 1991).

Isopods in general are detritivores and scavengers as adults and immatures. Juveniles feed largely upon microbial foods such as algae and bacteria. They also feed upon dead organic matter. Adults will include live prey items in their diet (Thorp and Covich 1991).

Current Threats (adapted from Hutchins and Culver 2007 and NatureServe 2008):

This species is highly adapted to seeps and springs. Protecting the groundwater is the key ingredient to long term viability of these populations. Potential threats to groundwater quality and quantity include pollution by agricultural fertilizers and pesticides, industrial chemical and wastewater spills, storm water run-off containing contaminants such as oils, heavy-metals and salts, soil compaction, siltation, pumping of water from the aquifer for domestic and industrial uses, and reduction of groundwater recharge due to increases in impervious surface area within a watershed. Upslope of the aquifers some potential exists for pollution from forestry practices and capture of surface run-off which might limit water reaching subterranean habitats.

Main factors Contributing to Vulnerability:

The key factors found to increase the vulnerability of *Caecidotea kenki* to climate change are minimal ability to disperse outside of occupied cave systems, highly restricted range, specialized groundwater habitats, increased groundwater demand and surface water capture expected due to increased frequency and duration of summer droughts. Natural gas extraction has the potential to negatively impact watersheds, including small springs and seeps within the range of this species in Pennsylvania. This cold-water isopod is likely sensitive to changes in the seasonal hydrology and temperatures of the aquifer. However, a groundwater system should be able to moderate climatic changes to some degree.

In the CCVI version 2.0, obligate cave species were automatically given a higher resistance rating to climate change impacts. According to the CCVI guidelines (NatureServe 2010) and the West Virginia Climate Change Vulnerability Assessment Report (Byers and Norris 2011), cave species are expected to better survive climate changes in their buffered underground habitats.

Protecting water quality and quantity in occupied watersheds by increasing forest cover, prohibiting mining activities, implementing best management practices for agriculture, and limiting the addition of impervious surfaces and further water withdrawal or storage can provide important protection against current and future threats.

References:

Byers, E. and S. Norris. 2011. Climate Change Vulnerability Assessment of Species of Concern in West Virginia. West Virginia Division of Natural Resources, Elkins, WV.

Hutchins, B. and D. C. Culver. 2007. Investigating rare and endemic pollution-sensitive subterranean fauna of vulnerable habitats in the NCR. Final report prepared for the U.S. National Park Service, National Capital Region. Available online at: http://www.nps.gov/prwi/naturescience/upload/Subterranean%20Fauna%20Report%20AU.pdf.

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. Available online at http://www.natureserve.org/explorer.

NatureServe. 2010. Guidelines for Using the Climate Change Vulnerability Index, release 2.0, 27April2010. NatureServe, Arlington, Virginia.

Thorp, J.H. and A.P. Covich (eds). 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., Boston, MA. 911pp.

INSECTS

Species: West Virginia White (*Pieris virginiensis*)
Global Rank: G3?
State Rank: S2S3
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability: Highly Vulnerable
Confidence: Very High

<u>Habitat:</u>

The West Virginia white is a weak-flying woodland butterfly seen in the springtime in moist, rich, shady woodlands and floodplains. Caterpillars feed on toothworts such as *Cardamine diphylla* and *C. concatenata*. Preferred nectar sources include spring beauty, toothwort, stonecrop, and violets (Allen 1997). This species needs relatively intact forests with a minimum amount of fragmenting features.

<u>Current Threats:</u>

The invasive garlic mustard (*Alliaria petiolata*) is spreading into areas once occupied by the native toothworts. West Virginia whites will lay their eggs on garlic mustard which is in the same family as the toothworts; however, the garlic mustard is toxic to the caterpillars (NatureServe 2008). Removal of garlic mustard from woods with this butterfly or large toothwort populations is highly recommended. Deer contribute to the spread of garlic mustard as they prefer to browse on native plants but not on the introduced garlic mustard. High deer densities also reduce the abundance and diversity of wildflowers, which can leave West Virginia whites without a steady supply of adult nectar food and caterpillar food plants.

Forest fragmentation degrades habitat for many forest species, but it is especially detrimental to West Virginia whites because it creates a host of problems. Development and timbering encourage the spread of garlic mustard by disturbing soils. Forest fragmentation may also encourage the penetration of forest habitats by the much more common cabbage white (*Pieris rapae*). The cabbage white prefers edge habitats to woodland interiors, and fragmentation increases edge habitat within forested sites. This increases the contact between West Virginia whites and cabbage whites. Cabbage whites carry parasites which can be spread to West Virginia white populations. West Virginia whites are reluctant to cross large forest openings or colonize new areas (Cappuccino and Kreiva 1985; Allen 1997; Finnell and Lehn 2007; NatureServe 2008). Because the butterfly avoids any open areas, a road with open canopy through the forest can be a barrier to dispersal. Other barriers include uncanopied streams and rivers, power lines, and unshaded fields. Habitat fragmentation prevents existing populations from spreading to new sites, or re-colonizing habitat previously occupied by the butterfly.

Main factors Contributing to Vulnerability:

The main factors contributing to climate change vulnerability are large scale changes in the amount and seasonality of soil moisture, the West Virginia white's association with cooler and higher altitude sites in the commonwealth, and its dependence upon a few host plants during the larval stage. Mitigating factors include the ability of adults to disperse relatively easily through suitable habitat, though many anthropogenic disturbances, including a wide variety of openings such as roads, developments, and fields, form barriers to dispersal. This species is not restricted to highly specialized habitats.

Increased summer soil droughts are predicted for Pennsylvania by climate models, and could lead to an increase in the amount and severity of forest fires (Shortle et al. 2009). West Virginia whites utilize woodland habitats that do not need disturbance to remain suitable. The widespread burning of habitats could be devastating to local populations.

The impacts from development of alternative energy sources are expected to be especially important particularly as it relates to population dynamics. Right-of-way infrastructure supporting alternate energy sources such as wind energy and natural gas are expected to further fragment many acres of land in forested habitats. West Virginia whites occur in fairly undisturbed habitats that support good populations of the food plant, and not every colony of toothwort supports the species. Other factors that affect the distribution of this moth, and metapopulation dynamics are likely a component. This species needs relatively intact forests with a minimum amount of fragmenting features such as clear-cuts, roads, and other rights-of-ways with open canopies overhead.

Disperal and movements: West Virginia whites are not strong fliers, but within extensive, contiguous, suitable forest with the food plant, they can be expected to move several kilometers or more. This is assuming the habitat is not fragmented by unshaded paved roads, powerlines, rivers, unshaded streams, etc. (NatureServe 2008). Therefore this species ranks as 'somewhat less vulnerable' under the 'dispersal and movements' question in the CCVI.

However, since individual butterflies are confined to their wooded habitats and will not fly out from underneath the canopy, dispersal rates are typically very weak (Finnell and Lehn 2007). This aspect of the butterflies' vulnerability is captured under the 'anthropogenic barriers' and 'predicted impact of land use changes resulting from human responses to climate change' questions of the CCVI.

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Species: Bog Copper (*Lycaena epixanthe*)
Global Rank: G4G5
State Rank: S2
State Wildlife Action Plan: High-level Concern Species
Climate Change Vulnerability: Highly Vulnerable
Confidence: Very High

Habitat:

The bog copper is typically found in acid bogs with cranberries and other heath family plants, but it is not restricted to bogs. It can also occur in fens and very wet acid sedge meadows with cranberries rather than true bogs. In the New Jersey Pine Barrens it can occur in a variety of acid wet situations, generally with a lot of sphagnum moss including ditches, infrequently mowed wet meadows, and wet burn scars (NatureServe 2008). Habitats may have some trees but are mainly open with permanently wet sunny substrates. It is important that the wetlands soils or sphagnum remain saturated for most or all of the year. Bog copper caterpillars feed on cranberries (both *Vaccinium macrocarpum* and *V. oxycoccos*), and while cranberries can grow well on less saturated sites, bog coppers do not occupy such habitats (NatureServe 2008). *Lycaena epixanthe* is usually excluded from commercial cranberry bogs by insecticides (Glassberg 1999).

Current Threats:

According to NatureServe (2008), the habitat is subject to peat mining in Maine (Opler, pers. comm.). Additional threats include fire, pesticides, succession, storm floods, and beaver damming which can eradicate local populations (Schweitzer, pers. obs.). These are only serious threats for isolated colonies of bog coppers. In fact these disturbances are needed over time to create new habitats. New habitats can be colonized by bog coppers if there are sufficient populations nearby and at least small intervening 'stepping stone' habitats with host plants that connect occupied and unoccupied habitats. Populations that occur in isolated bog habitats and are not part of a large wetland complex are vulnerable to localized extinctions without recolonization.

Main factors Contributing to Vulnerability:

The main factors leading to species vulnerability to climate change are limited dispersal ability, habitat specificity (bogs and other wetlands with cranberry), dependence on other species to create habitat (beaver can both destroy and over the long term create habitat), host plant specificity (cranberries) and association with cooler, higher elevation wetlands in Pennsylvania. Negative impacts to water quality and hydrology, and fragmentation of habitat obstructing colonization movements are expected in light of development of alternative energy, particularly natural gas from the Marcellus shale formation which is especially rich in the core of the bog copper's range in the NE corner of Pennsylvania.

Dispersal and movements: The bog copper is not a migratory species. Adults generally stay in their small core habitats, but they do occasionally move along sunny stream banks, especially if the food plant is present in limited amounts along the waterway (NatureServe 2008). The bog coppers can be a good colonizer of new habitats in wetland complexes where suitable habitat is frequently encountered on the landscape. Still, most adults are closely tied to their small habitats and 2 km is expected to separate populations in most cases, at least in the absence of small "stepping stone" habitat patches (NatureServe 2008). In areas where habitats are widely scattered (>10 km apart) and isolated such as certain bogs in Pennsylvania and New Jersey, most seemingly suitable habitats are unoccupied (NatureServe 2008). West Virginia has a disjunct population in one locality that has been unable to colonize nearby bogs (Allen 1997). These observations suggest lack of long distance movements. In the balance, this species was ranked as neutral in the ability for dispersal/movement especially in areas of Pennsylvania where suitable wetland habitat is abundant and relatively contiguous.

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Species: Grizzled Skipper (*Pyrgus wyandot*)
Global Rank: G1G2Q
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Moderate

<u>Habitat (adapted from Schweitzer 1989 and NatureServe 2008):</u>

The grizzled skipper butterfly is an Appalachian Mountain habitat specialist that requires shale barren habitats with abundant exposed crumbly rock or soil. Shale barrens are semi-open shale slopes with sparse herbaceous vegetation and tend to be surrounded by scrubby oak or oak-hickory woodlands, often with a component of Virginia pine (*Pinus virginiana*). These dry, shale slopes should favor plentiful growth of the larval host plant, Canada cinquefoil (*Potentilla canadensis*) and tufted grasses like broom-sedge (*Andropogon virginicus*). Occupied sites also support a variety of spring plants such as spring beauty (*Claytonia* spp.), phlox (*Phlox subulata*), and birdsfoot violet (*Viola pedata*) which provide nectar food for adults.

The caterpillars feed on Canada cinquefoil, which is a very common species that can be found growing in lawns. However, the grizzled skipper is restricted to a narrow range of very hot rock outcrop habitats with the host plant. Grassy roads, right-of-ways, and other disturbed areas on south- or west-facing slopes over shale substrates can be suitable habitat if they maintain the appropriate plant community structure with Canada cinquefoil as a primary component. Occupied sites are always in close proximity (within 30 m) of densely wooded areas. Adults seldom occur more than about 30 m from forested areas even if host plants occur in open canopy areas adjacent to the forest edge. Another key site characteristic is the presence of a source of moisture, such as temporary or permanent streamlets, or even muddy puddles in deep wheel ruts. Perhaps for this reason, the grizzled skipper is not typically found on ridges, but more often occurs along the bases of slopes.

<u>Current Threats (adapted from NatureServe 2008 and Schweitzer 1989):</u>

The grizzled skipper is extremely vulnerable to gypsy moth spraying. Gypsy moth spraying eliminated most known Appalachian populations and the New Jersey ones as well. Grizzled skipper habitat is located on oak-dominated ridges which are often sprayed for gypsy moth control. Eggs are laid on the host plant in open habitats, but always near the edge of woods. Larvae feeding on cinquefoil plants at these woodland edges and openings are therefore unprotected by the tree canopy and are positioned to have direct contact with gypsy moth spray. The larvae would all be hatched and feeding as early instars by or just after a typical spray date in mid-May which greatly increases their vulnerability to applications of *Bacillus thuringiensis* var. *kurstaki* (Btk). Peacock et al. (1998) found that among 42 tested species of native butterflies and moths, all first and second instar caterpillars had 90-100% mortality from Btk application regardless of the species. Grizzled skipper caterpillars also feed over most of the summer, which increases their exposure to persistent toxins sometimes used to control gypsy moths (e.g., Diflubenzuron). Diflubenzuron is a broad-spectrum insecticide universally toxic to several types of arthropods, while Btk targets butterfly and moth caterpillars (Order Lepidoptera). Btk does not persist in the environment since it breaks down within 10 days, while Diflubenzuron persists on treated foliage until leaf drop in the fall, after which the chemical can move into the leaf litter layer and into forest streams (Butler 1998). Large open areas known to support grizzled skippers could be excluded from spray programs, but smaller openings or undocumented sites are unlikely to be avoided. Populations appear to be so small or sparse that recovery is far less likely than with more abundant species of butterflies and moths.

Population numbers are now so low that additional threats are exacerbated. Minor fluctuations in the environment could cause colonies to disappear. Low numbers and fragmentation greatly increase this threat, and the grizzled skipper probably cannot survive unless some metapopulation function is restored. Broadcast herbiciding of powerlines would also be a very potent threat considering that powerline corridors were major habitats in the 1980s and will almost certainly be important if the grizzled skipper ever recovers. Powerlines appear to be a better dispersal corridor than any kind of natural feature. Even collectors may constitute a threat to remaining colonies, although collecting has not been linked to the overall population decline.

<u>Main factors Contributing to Vulnerability:</u>

The main factors contributing to climate change vulnerability are large scale changes in the amount and seasonality of soil moisture, the physical habitat specificity of the grizzled skipper, and its dependence upon one host plant during the larval stage. A mitigating factor is the ability of adults to disperse relatively easily through suitable habitat. The region of Pennsylvania where *Pyrgus wyandot* still occurs has experienced slightly lower than average precipitation variation in the past 50 years, making populations somewhat vulnerable to future changes in precipitation. The impacts of development of alternative energy sources, and microhabitat changes in seasonal soil moisture levels and temperatures, are expected to be especially important for grizzled skipper caterpillars, pupae, and the host plant, Canada cinquefoil.

The impacts of climate change on grizzled skipper microhabitat (positive, negative, or neutral) cannot be predicted at this time without more data on microhabitat requirements of the species. Increased summer soil droughts are predicted by climate models and could lead to an increase in the amount and severity of forest fires (Shortle et al. 2009). Forest fires could create new habitat and reset succession, which is thought to threaten some grizzled skipper populations in New York, Virginia, and Michigan. However, known extant habitat in Pennsylvania is shale barrens and openings, which do not require disturbance to remain open, and burning of small shale barrens habitats could extirpate local populations. Fire-related mortality of near 100% would be expected because the larvae and pupae remain above the soil surface year-round (Allen 1997) and therefore are very vulnerable to fire.

Infrastructure development supporting alternate energy sources such as wind energy and natural gas are going to create many acres of disturbed land in forested habitats. Under certain conditions of soil, bedrock, moisture, and aspect, and with proper type and timing of vegetation management, these disturbed lands could become potential habitat for the species. Grizzled skippers could be encouraged with plantings of Canada cinquefoil and other native nectar plants. Right-of-way corridors could then play an important role in providing habitat and promoting species dispersal, especially if climate change causes dry oak woodlands to leaf out earlier in the season, potentially blocking adult movement (see comments under dispersal and movements).

These developments would require considerable investment in planning and resources to maximize the potential benefit for this species. Therefore, the impacts of predicted land use changes could range from somewhat decreasing to somewhat increasing vulnerability. Infrastructure development could easily have negative impacts as well. Broadcast herbiciding of rights-of-ways would eliminate their usefulness as habitat corridors. Undocumented populations and currently unoccupied (but ultimately recolonizable) habitat could be inadvertently destroyed in right-of-way development. Pre-development surveys to look for potential habitat would be needed to avoid destruction of occupied or potentially occupied habitats.

This species is well adapted to hot microhabitats (shale barrens), but details on the optimal range and seasonality of soil temperature and moisture for the development of larvae and overwintering pupae are unknown. The larvae live in leaf shelters created by rolling a host plant leaf with silk. Larvae pupate in late summer and spend the winter in leaf shelters created by tying together several leaves of the host plant or of a nearby plant (Allen 1997). Soil moisture is also important for the host plant Canada cinquefoil, which can suffer under drought conditions. For example, a decrease in the abundance of host plants on some historic West Virginia sites was attributed to drought (NatureServe 2008).

Dispersal and movements: While adults seem to be reluctant to move far from woods or to leave their edaphic habitat, they can disperse within ridge systems, especially along powerlines and dirt roads. No good movement data exists, but prior to large scale gypsy moth spraying, few suitable habitat patches within occupied edaphic features were regularly vacant. This was still true of unsprayed areas in Pennsylvania, Maryland and West Virginia in the mid 1980s (see Schweitzer (1989) report on Candidate Insecta to USFWS), although, by the 1990s nearly all suitable habitats were vacant.

The oak woodlands on dry shale ridges surrounding grizzled skipper habitats leaf-out late in the spring, usually after the grizzled skipper flight season. Prior to leaf-out in the spring, it is very likely that adults move through the forest understory. Teneral adults (freshly emerged) have been found in forested areas indicating some oviposition occurs there. Grizzled skipper habitat therefore may not be quite as discrete as it appears and main breeding sites are rarely confined to where the food plant occurs. While there are no precise data, it is obvious this species used to move fairly widely through suitable or marginal habitats and was a good colonizer within its small range. Metapopulation dynamics are likely important for the grizzled skipper; it may require 50 acres (20 ha) or more for population maintenance, with suitable breeding habitat scattered throughout.

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Species: Cobblestone Tiger Beetle (*Cicindela marginipennis*)
Global Rank: G2
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: High

Habitat:

Cobblestone tiger beetles are found on the edges and islands of small to medium sized rivers with swift flowing water. They are restricted to scour areas along these rivers where the substrate is comprised of wet pebbles, cobblestone sand, and sparse vegetation. The larvae dig burrows in pockets of wet sand found interspersed among cobblestones (Pearson et al. 2006).

Distribution of this species is limited to the eastern United States and southeastern Canada. In Pennsylvania, this tiger beetle is known historically from three large river systems in the eastern portion of the state. Recent data is lacking for Pennsylvania, but there is suitable habitat in the upper Susquehanna and Delaware rivers that merit surveys for cobblestone tiger beetles.

Current Threats:

The most significant threats to the cobblestone tiger beetle are alteration and destruction of habitat from impoundments and other alterations of stream channels such as channelization, water quality degradation (primarily from urbanization, agriculture, pesticides and other chemicals), and loss of riparian forests.

Main factors Contributing to Vulnerability:

The cobblestone tiger beetle is a terrestrial beetle specializing in river scour habitats. Species vulnerability to climate change is linked to factors expected to change natural stream hydrology and disturbance regimes. Regions of Pennsylvania where the cobblestone tiger beetle occurred historically have experienced average precipitation variation in the past 50 years. Therefore, populations are not expected to be extremely adapted or maladapted to changes in precipitation patterns. Shifts in precipitation patterns are expected to create higher winter and spring flows, and more frequent and severe floods (Shortle et al. 2009). This could be particularly problematic for the air-breathing larvae living in burrows at the edges of a river floodplain. However, these events can also create new habitat. According to NatureServe (2008), as with other tiger beetles, survival may be substantial if inundation is only for a few days and the habitat is not physically demolished. Long term inundation would eradicate an occurrence. Floods surely kill a lot of individuals but occurrences generally survive them. However, this could be jeopardized by either low areas of occupancy or small numbers. Acciavatti et al. (1992) reported an instance where this species survived, and may have benefited from, a devastating flood. Thus, flooding of known sites should not be assumed to eradicate them. A mitigating factor is the ability of adults to disperse relatively easily along stream corridors to colonize newly created habitat.

Whether or not there will be suitable habitat nearby to be colonized is a pertinent question. Many populations have become isolated because of historical loss of habitat due to dam construction. Cobblestone tiger beetle populations once known from the southern Susquehanna and Schuylkill river systems may have been extirpated due to construction of dams. Climate change may increase incentives to build/enlarge dams for hydroelectric power or water storage. It is not clear how much additional dam development would occur on stream reaches historically supporting populations of cobblestone tiger beetles. Therefore the predicted impact of land use changes resulting from human responses to climate change was ranked as 'neutral to somewhat increasing' vulnerability.

Tiger beetles are adapted to specific thermal and hydrological conditions, therefore, changes in these conditions are likely to impact basic tiger beetle biology (Pearson and Vogler 2001). Climate change will likely alter the seasonality and range of moisture and temperatures experienced by this species, but more research is needed to determine whether the effects would be generally positive, negative, or neutral.

An additional global climate change related threat is natural gas extraction and its associated impacts on forest integrity and water quality, and its potential impacts on climate change itself.

Some of the current and projected threats could be mitigated with removal of dams where they are not critical to energy production, water storage, or protection of infrastructure. Protection and expansion of riparian buffers around medium to large streams and rivers is critical, and should include protection from off-road vehicle use.

Dispersal and movements: The cobblestone tiger beetle was historically known from a few locations on occupied streams. The species likely moved along a stream or river system to find suitable river scour habitats as they formed after floods.

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Species: Appalachian Tiger Beetle (*Cicindela ancocisconensis*)
Global Rank: G3
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Very High

Habitat:

Adult Appalachian tiger beetles are found on sand bars, shaded beaches, gravel areas, and sparsely vegetated dry sandy openings along forested rivers. Larvae live in burrows dug in the sandy-loam soils of upper flood plains, often removed some distance from the water's edge (Pearson et al. 2006).

Distribution of this species is limited to rivers in hilly areas of the eastern U.S. and southeastern Canada. Historical data indicate that the Appalachian tiger beetle was formerly more widely distributed, occurring as far west as Indiana or Illinois. It is rare or missing from most of its former range along the Ohio River (Pearson et al. 2006). In Pennsylvania, this tiger beetle is known from one clean, cold, mountain stream watershed in the Appalachian Mountain Section of the Ridge and Valley Physiographic Province. There is much suitable habitat in Pennsylvania. Further surveys are needed to look for additional populations.

Current Threats:

The most significant threats to the Appalachian tiger beetle are alteration and destruction of habitat from impoundments and other alterations of stream channels, water quality degradation (primarily from urbanization, agriculture, pesticides and other chemicals), and loss of riparian forest.

Main factors Contributing to Vulnerability:

The Appalachian tiger beetle is a terrestrial beetle specializing in stream scour habitats. Species vulnerability to climate change is linked to factors expected to change natural stream hydrology and disturbance regimes. Regions of Pennsylvania where the Appalachian tiger beetle occurs have experienced slightly lower than average precipitation variation in the past 50 years. This makes populations somewhat vulnerable if precipitation patterns become more extreme in the future (CCVI section C2bi). Shifts in precipitation patterns are expected to create higher winter and spring flows and more frequent and severe floods (Shortle et al. 2009). This could be particularly problematic for the air-breathing larvae living in burrows at the edges of the floodplain, but these events can also create new habitat. According to NatureServe (2008), as with other tiger beetles, survival may be substantial if inundation is only for a few days and the habitat is not physically demolished. Long term inundation would eradicate an occurrence. Floods surely kill many individuals, but diminished populations generally survive. However, this could be jeopardized by either low areas of occupancy or small numbers. Acciavatti et al., (1992) report an instance where this species survived, and may have benefited from, a "devastating flood." Thus flooding of known sites should not be assumed to eradicate them. River dynamics may be an important habitat factor. A mitigating factor is the ability of adults to disperse relatively easily along stream corridors to colonize newly created habitat.

Whether or not there will be suitable habitat nearby to colonize is a pertinent question. Many populations have become isolated because of historical loss of habitat due to dam construction. Climate change may increase incentives for building/enlarging dams for hydroelectric power or water storage. It is not clear how much more dam development would occur on stream reaches supporting populations of Appalachian tiger beetles.

Tiger beetles are adapted to specific thermal and hydrological conditions, therefore, changes in these conditions are likely to impact basic tiger beetle biology (Pearson and Vogler 2001). Climate change will likely alter the seasonality and range of moisture and temperatures experienced by this species, but more research is needed to determine whether the effects would be generally positive, negative, or neutral.

Related to temperature and moisture microhabitats along mountain streams is the decline of eastern hemlocks (*Tsuga canadensis*) in Pennsylvania. Eastern hemlock is a keystone species that cools streams and streamside habitats. Widespread decline and death of hemlocks, especially in warmer parts of its range, is attributed to pests including the hemlock woolly adelgid (*Adelges tsugae*). Hemlock woolly adelgid is expected to increase with climate change. Hemlocks are more likely to succumb under the stress of a pest infestation when combined with other environmental stressors such as drought (Parker and Skinner 2005). Summer soil moisture droughts are anticipated to increase with increasing temperatures (Shortle et al. 2009). Hemlock mortality is currently most severe in southeastern Pennsylvania where milder winters allow successful overwintering by hemlock woolly adelgid. The range and abundance of hemlock woolly adelgid is moving in a northerly and westerly direction (Shortle et al. 2009). Cooler mountainous areas will gradually become more hospitable to overwintering hemlock woolly adelgid as climate change produces milder winters. For this reason the factor ‘Dependence on other species to generate habitat’ effect on vulnerability was rated as ‘Somewhat increase’, as loss of Eastern hemlock is expected to affect the temperature and moisture conditions of mountain streams and their riparian zones.

An additional global climate change related threat is natural gas extraction and its associated impacts on forest integrity, water quality, and its potential impact on climate change itself.

Some of the current and projected threats could be mitigated with removal of dams where they are not critical to energy production, water storage, or protection of infrastructure. Protection and expansion of riparian buffers around medium to large streams and rivers is critical, and should include protection from off-road vehicle use. Continued research and treatment of hemlock woolly adelgid is needed to try to protect hemlocks and the vital ecological role they play in maintaining cold water stream habitats. Plantings of replacement evergreen species not susceptible to hemlock woolly adelgid may be needed as an emergency measure to protect streams. Spruces and pines native to the northeastern United States should be used in such situations. Non-native species such as Norway spruce should be avoided.

Dispersal and movements: Appalachian tiger beetles tend to be patchily distributed, perhaps moving along a stream system to find new river scour habitats that form after floods. Colonies are usually small and located within 60 m of the water's edge, with rare reports of occurrences in wet sandy areas up to 2.5 km from the nearest water (Pearson et al. 2006).

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Species: Green-faced Clubtail (*Gomphus viridifrons*)
Global Rank: G3G4
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Very High

Habitat:

The green-faced clubtail dragonfly is found in clean streams in a forested landscape. These streams are typically highly oxygenated, small to large in size, with a moderate-gradient, and substrate of gravel-sand and lightly silted rocks (Dunkle 2000, NatureServe 2008). NatureServe (2008) reports that the species is relatively widespread, but very localized, fragmented, and requires very good water quality. In Pennsylvania, nymphs have been collected from slow to swift flowing waters, 3 cm to 25 cm in depth, in sand/detritus/gravel substrates (Evans 2002). Adults have a short flight period and are active almost exclusively over water or in trees where they hunt insects; therefore, this species can be easily overlooked and is difficult to collect. More surveys are needed to determine the range and microhabitat preferences for this species in Pennsylvania.

The green-faced clubtail dragonfly was thought to be extirpated from the state because for nearly 100 years there were no new records. In the early 1990s, large numbers of the species were rediscovered on the Clarion River and several new records followed at other sites. These unexpectedly large populations localized in Pennsylvania justify making this species a responsibility species (Rawlins 2007).

Current Threats:

The most significant threats to this species are alteration and destruction of habitat from impoundments, channelization, sedimentation, and other alterations of stream channels; water quality degradation from urbanization, acid mine drainage, agriculture, pesticides and other chemicals; spread of invasive aquatic species; fragmentation of forests around headwater streams; loss of riparian forest; and direct mortality from vehicle collisions where roads intersect habitat.

Main factors Contributing to Vulnerability:

Throughout its range, the green-faced clubtail dragonfly appears to be limited to waterways with high quality water (NatureServe 2008). Climate change vulnerability for the green-faced clubtail is linked to factors expected to impact water quality and hydrology. These factors are expected to be important for many other clubtail dragonflies (family Gomphidae) of high quality stream and river habitats. Regions of Pennsylvania where green-faced clubtail dragonfly occurs have experienced slightly lower than average precipitation variation in the past 50 years, making populations somewhat vulnerable to future changes in precipitation. Pennsylvania is expected to have higher winter and spring stream flows, but lower summer and fall flows. Changes in the timing of peak spring flows, higher temperatures and lower flows in the summer and fall, and changes in stream channels due to more severe precipitation and flooding events are expected to negatively impact aquatic ecosystems (Shortle et al. 2009*)*. Larvae utilize specific microhabitats within a stream as they develop over two or more years, and shifts in the hydrologic regime could be problematic. A mitigating factor is the ability of adults to disperse relatively easily along stream corridors to colonize new habitats.

Other global climate change related threats include construction of dams on small to large moderate gradient streams and rivers for hydroelectricity, flood control, or water storage; natural gas extraction and its associated impacts on forest integrity and water quality; warmer air temperatures and reduced watershed forest cover leading to increased water temperatures and lower dissolved oxygen levels; facilitated spread of invasive aquatic species due to milder winters and warmer waters.

Some of the current and projected threats could be mitigated with removal of dams where they are not critical to energy production, water storage, or protection of infrastructure. Protection and expansion of riparian buffers around occupied high quality streams and their headwaters is critical. Increasing percent forest cover in occupied watersheds could be used towards carbon offsets while improving water quality for this species. Long term monitoring of water quality and hydrologic regime on occupied reaches of streams could provide important insight into habitat requirements and limits, combined with information on population stability or decline.

Dispersal and movements: This species does not exhibit migratory behavior; however it is a relatively strong flier and should be capable of dispersing several kilometers in a day along stream corridors. River currents can also carry eggs or young larvae downstream, potentially dispersing them to suitable unoccupied habitat.

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Species: Rapids Clubtail (*Gomphus quadricolor*)
Global Rank: G3G4
State Rank: S1S2
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Very High

Habitat:

In Pennsylvania, the rapids clubtail dragonfly is most commonly associated with swift medium to large streams and rivers. The rapids clubtail prefers habitats with small rapids or riffles intermixed with quiet muddy pools. Adult males prefer in-stream boulders and bedrock outcrops for perching. Young adults can be found far from their stream of origin as they feed and mature prior to returning to stream habitats to breed. Larvae develop in muddy pools below shallow rapids, and utilize dense emergent streamside vegetation for emergence. More surveys are needed to determine the range and microhabitat preferences for this species in Pennsylvania.

Current Threats:

The most significant threats to the rapids clubtail are alteration and destruction of habitat from impoundments, dredging, channelization, sedimentation, and other alterations of stream channels; water quality degradation from urbanization, acid mine drainage, agriculture, pesticides and other chemicals; spread of invasive aquatic species; fragmentation of forests around headwater streams; loss of riparian forest; and direct mortality from vehicle collisions where roads intersect habitat.

Main factors Contributing to Vulnerability:

Climate change vulnerability for the rapids clubtail is linked to factors expected to impact water quality and hydrology. These factors are expected to be important for many other clubtail dragonflies (family Gomphidae) of good quality stream and river habitats. Regions of Pennsylvania where rapids clubtail occurs have experienced slightly lower than average precipitation variation in the past 50 years, making populations somewhat vulnerable to future changes in precipitation. Pennsylvania is expected to have higher winter and spring stream flows, but lower summer and fall flows. Changes in the timing of peak spring flows, higher temperatures and lower flows in the summer and fall, and changes in stream channels due to more severe precipitation and flooding events are expected to negatively impact aquatic ecosystems (Shortle et al. 2009). Even though the rapids clubtail does not require highly specialized or limited habitats, shifts in the hydrologic regime could be problematic. Larvae utilize specific microhabitats within a stream as they develop over two or more years, and appear to be sensitive to landscape-scale changes in land use that affect water temperature and quality (COSEWIC 2008). A mitigating factor is the ability of adults to disperse relatively easily along stream corridors to colonize new habitats.

Other global climate change related threats include construction of dams on medium to large rivers for hydroelectricity, flood control, or water storage; natural gas extraction and its associated impacts on forest integrity and water quality; warmer air temperatures and reduced watershed forest cover leading to increased water temperatures and lower dissolved oxygen levels; facilitated spread of invasive aquatic species due to milder winters and warmer waters.

Some of the current and projected threats could be mitigated with removal of dams where they are not critical to energy production, water storage, or protection of infrastructure. Protection and expansion of riparian buffers around medium to large streams and rivers is critical. Increasing percent forest cover in occupied watersheds and their headwaters could be used towards carbon offsets while improving water quality for this species. Long term monitoring of water quality and hydrologic regime on occupied reaches of streams could provide important insight into habitat requirements and limits, combined with information on population stability or decline.

Dispersal and movements: This species does not exhibit migratory behavior, and does not like to stray far from water. The maximum known dispersal inland is approximately 800 m (COSEWIC 2008). However, it is a relatively strong flier capable of dispersing several kilometers in a day along river corridors. River currents can also carry eggs or young larvae downstream, potentially dispersing them to suitable unoccupied habitat.

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Species: Flypoison Borer Moth (*Papaipema* sp. 1)
Global Rank: G2G3
State Rank: S2
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Very High

Habitat:

The flypoison borer moth can utilize a range of woodland and forest habitats supporting good populations of the food plant. Habitats are wooded to forested situations on acid soils where the caterpillar food plant, fly-poison (*Amianthium muscaetoxicum*), is abundant. Most sites are oak dominated forests on acidic soils; some sites are or include pitch pine scrub-oak barrens; some are mostly mixed northern hardwoods (NatureServe 2008).

The host plant, fly-poison, is found mostly in the eastern half of the state with concentrated populations in northeastern Pennsylvania (Rhoads and Klein 1993). The plant is frequent in woods and barrens, especially in the mountains (Rhoads and Block 2000). Distribution of the flypoison borer moth is limited to habitats that support good populations of the food plant, however, not every good population of fly-poison has been found to support the flypoison borer moth. There appear to be other factors that affect the distribution of the moth, but those factors are currently unknown. This species is currently known from nine counties in Pennsylvania and has not been documented in any surrounding states. For reasons of endemism, rarity, and use of a single host plant for larval development, the flypoison borer moth is a responsibility species (Rawlins 2007).

Current Threats:

The most serious threats are habitat loss and fragmentation (usually from development), fires (especially September through May), and spraying for gypsy moth control (especially April-May) (NatureServe 2008). Fires are most problematic during the dormant season from September through early May when flypoison borer moth eggs are exposed on the host plant. Survivorship of fire later in the summer greatly increases after the caterpillars bore into the bulb of the host plant. Severe deer browsing has been an ecological problem rangewide for a decade or two, but this species has apparently not been negatively impacted and may have even benefited. Deer conspicuously avoid the new growth of fly-poison in April and early May making it sometimes virtually the only herbaceous growth present (observations by D. Schweitzer in the 1980s).

Gypsy moth control is used to protect timber resources in habitats occupied by *Papaipema* sp. 1. The level of mortality in flypoison borer moth caterpillars from gypsy moth control is related to the timing and number of applications and the type of spray. Regardless of the treatment used, spraying for gypsy moth should be a concern if a large extent of the population is scheduled to be sprayed, since it is not known exactly when or for how long the first instar larvae would be exposed before burrowing into the host plant bulb.

Bacillus thuringiensis var. *kurstaki* (Btk) is commonly used in Pennsylvania to control gypsy moths because it targets butterfly and moth caterpillars and is not toxic to a wider spectrum of arthropods outside of the Order Lepidoptera. Also, Btk does not persist in the environment since it breaks down within ten days (Butler 1998). It is not currently known if flypoison borer moth larvae are susceptible to Btk. Peacock et al. (1998) showed that among 42 tested species of native butterflies and moths, all first and second instar caterpillars had a 90-100% mortality regardless of species. Older caterpillars in the third or later instar varied in susceptibility, even within one genus. Flypoison borer moth eggs hibernate (typical of the genus), and the larvae probably hatch in May when the potential for Btk exposure is greatest since spraying typically also occurs at this time. The tree canopy may offer some protection by intercepting the spray and preventing much of the Btk from reaching the base of the host plant where the newly hatched flypoison borer moth caterpillars are located.

Diflubenzuron (trade name Dimilin) is a broad-spectrum insecticide universally toxic to several types of arthropods including butterfly and moth caterpillars. Diflubenzuron could be more problematic to *Papaipema* larvae because it persists on treated foliage until leaf drop in the fall. When leaves fall to the forest floor, the chemical becomes a part of the leaf litter layer and may enter into forest streams via runoff (Butler 1998).

<u>Main factors Contributing to Vulnerability:</u>

The main factors contributing to climate change vulnerability are large scale changes in the amount and seasonality of soil moisture, the flypoison borer's endemism to Pennsylvania, its association with cooler and higher altitude sites in the commonwealth, and its dependence upon one host plant during the larval stage. Mitigating factors include the ability of adults to disperse relatively easily through suitable habitat; the species is not restricted to particularly specialized habitats.

The regions of Pennsylvania where flypoison borer moth occurs have experienced slightly lower than average precipitation variation in the past 50 years, making populations somewhat more vulnerable to future changes in precipitation. Increased summer soil droughts are predicted by climate models, and could lead to an increase in the amount and severity of forest fires (Shortle et al. 2009). Forest fires could maintain some barrens habitats that support fly-poison. However many sites are woodlands that do not require disturbance to remain suitable for fly-poison. The widespread burning of habitats at the wrong time of year (September through May) could be devastating to local populations. Fire-related mortality at this time of year would be expected to be near 100% because the eggs are above the soil surface and on the outside of the fly-poison lily plant, making them very vulnerable to fire (NatureServe 2008).

The impacts of development of alternative energy sources are expected to be important especially as it relates to population dynamics and the health of populations of its food plant. Right-of-way infrastructure supporting alternate energy sources such as wind energy and natural gas are expected to further fragment many acres of land in forested habitats. Flypoison borer moth occurs in fairly undisturbed habitats that support good populations of the food plant.

Dispersal and movements: A few adults have been captured up to several miles from known habitat indicating that this species is to some extent dispersive, as are most borers in the genus *Papaipema* (NatureServe 2008).

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Species: Northern Metalmark (*Calephelis borealis*)
Global Rank: G3G4
State Rank: S2
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Moderate

Habitat (adapted from NatureServe 2008):

The northern metalmark and its larval host plant, the roundleaf ragwort (*Packera obovata*), have specific habitat requirements. In Pennsylvania, the butterfly is closely associated with limestone and shale barrens habitats. Sites tend to have close access to water from sources such as streams, and adults prefer to nectar on a variety of flowers.

Current Threats (adapted from NatureServe 2008):

Habitat loss is the most serious threat to the northern metalmark in Pennsylvania. Current records are mostly found along the Appalachian ridges. Historical records from the eastern part of the state are from sites that have been lost to development. Spraying for gypsy moth control is another threat. Northern metalmark caterpillars overwinter after their first summer then resume feeding the following April at the time spraying for gypsy moth takes place. Loss of the host plant due to displacement by exotic plants and excessive deer browsing can negatively impact northern metalmark populations.

Main factors Contributing to Vulnerability:

The main factors contributing to climate change vulnerability of the northern metalmark are changes in the amount and seasonality of soil moisture, the physical habitat specificity of the species, dependence on one host plant during the larval stage, small habitat and population sizes, and the relatively sedentary nature of adults. The region of Pennsylvania where the northern metalmark occurs (currently and historically) has experienced slightly lower than average precipitation variation in the past 50 years, making populations somewhat vulnerable to future changes in precipitation. The impacts from development of alternative energy sources and microhabitat changes in seasonal soil moisture levels and temperatures are expected to be especially important for northern metalmark caterpillars, pupae, and the round-leaved ragwort host plant.

The impacts of climate change on northern metalmark microhabitat (positive, negative, or neutral) cannot be predicted at this time without more data on microhabitat requirements of the species. Increased summer soil droughts are predicted by climate models, and could lead to an increase in the amount and severity of forest fires (Shortle et al. 2009). Forest fires could create new habitat and reset succession, which could benefit the species. However, known extant habitats in Pennsylvania are shale barrens and openings, which do not require disturbance for maintenance, and burning of small shale barrens habitats could extirpate local populations.

This species appears to be adapted to warmer microhabitats, but details on the optimal range and seasonality of soil temperature and moisture for the development of overwintering larvae and pupae are unknown. Northern metalmark caterpillars overwinter by hibernating in plant duff at the base of the host plant until spring. Soil moisture is also important for the caterpillar food plant. Roundleaf ragwort is found in moist fields, woods, and calcareous slopes (Rhoads and Block 2000). It prefers soils in the mid-moisture range, and does not tolerate extremely dry or extremely wet conditions (Landis and Fiedler 2006).

Infrastructure development supporting alternate energy sources such as wind energy and natural gas are likely to create many acres of disturbed land in forested habitats. Under certain conditions of soil, bedrock, moisture, and aspect, and with proper type and timing of vegetation management, these disturbed lands could become potential habitat for northern metalmark. Northern metalmarks could be encouraged with plantings of roundleaf ragwort and other native nectar plants. Right-of-way corridors could then play an important role in providing habitat and promoting species dispersal.

These developments would require considerable investment in planning and resources to maximize the potential benefit for this species. Therefore, the impacts of predicted land use changes could range from somewhat decreasing to somewhat increasing vulnerability. Infrastructure development could easily have negative impacts as well. Broadcast herbiciding of rights-of-ways would eliminate their usefulness as habitat corridors. Undocumented populations and currently unoccupied (but ultimately recolonizable) habitat could be inadvertently destroyed in right-of-way development. Pre-development surveys for potential habitat would be needed to avoid destruction of occupied or potentially occupied habitats.

Dispersal and movements: Northern metalmark populations are small and very localized in Pennsylvania. Adults are slow and weak fliers (Allen 1997) and are occasionally encountered only within their preferred habitats. Metapopulation dynamics are very important for long term survival of this species in a locale. Multiple small populations scattered across a landscape with corridors of wetlands, forests, streams, and even right-of-ways will help maintain this species into the future, allowing individuals to travel between occupied habitats and colonize new areas (NatureServe 2008).

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Species: Regal Fritillary (*Speyeria idalia*)
Global Rank: G3
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Very High

<u>Habitat (adapted from NatureServe 2008):</u>

The regal fritillary is associated with tall-grass prairie and wet fields and meadows in the core of its range in the Midwest. This butterfly formerly ranged over much of the eastern United States including Pennsylvania where it was found in a variety of open and often wet meadows, pastures, old fields, and hayfields, mostly created by humans (Glassberg 1999; NatureServe 2008). The last remaining population in Pennsylvania is associated with three main habitat components: violet food plants (*Viola* spp.) for larvae, adult nectar sources, and native warm season bunch grasses for larvae, pupae, and resting adults (pers. comm. Mark Swartz).

NatureServe (2008) further reports that treed habitats seem to be effective barriers to adults, but species can occur in savanna if trees are sparse or clumped. Absence of this species in prairie preserves is a significant negative indicator for community integrity and probably reflects failure to have recovered from past management practices such as complete burns and/or small patch size. Studies by Ann Swengel in Wisconsin and Missouri indicate that this species is negatively impacted by prescribed burning at normal frequencies. Others have suggested the same. High densities at some unburned Missouri sites and an apparent substantial increase in Pennsylvania after cessation of burning support her views. Schweitzer suspects (pers. comm.), based mostly on eastern habitats and direct observations of adults in Rhode Island, that subspecies *Speyeria idalia idalia* preferred recently or currently grazed areas and many references to it mention pastures. While more data are needed, it appears that there is a major difference between eastern and western subspecies in their ability to utilize artificial habitats such as hayfields and non-prairie pastures. This species may require relatively large habitats on the order of perhaps 50 ha for a marginally viable occurrence.

Subspecies Status: Williams (2002) presents evidence that eastern populations represent a subspecies (*Speyeria idalia idalia*) distinct from western populations (*Speyeria idalia occidentalis*) (NatureServe 2008). The most current and comprehensive molecular evidence to date has been gathered by Dr. Jason Weintraub (Academy of Natural Sciences) and his colleagues. Their data does not support the validity of "eastern" and "western" subspecies of Speyeria idalia (Weintraub pers. comm.). However, morphological, genetic, and habitat differences do suggest that regal fritillaries in Pennsylvania are significant on a population (haplotype) level, differing in some ways from western populations (NatureServe 2008, Weintraub pers. comm.). Therefore, on factors of rarity, genetic distinctness, and Pennsylvania relictual occurrence, this species is a Pennsylvania responsibility species (Rawlins 2007).

Current Threats:

The regal fritillary was historically widespread and common but declined precipitously in recent years and is now extirpated in all eastern states except Pennsylvania and Virginia. This is a large, attractive, conspicuous species that is not easily overlooked. The regal fritillary does not require pristine or extremely specialized habitats in Pennsylvania. It can inhabit upland forests, clearings, grasslands, as well as marshy or even swampy areas across its range (Rawlins 2007).

According to NatureServe (2008), the regal fritillary has declined for uncertain reasons, though a combination of factors are likely at play. These threats include loss and fragmentation of habitat to agriculture (other than pasture or hayfield) and development, conversion of pastures and hay fields to plowed croplands, reforestation, pesticides including gypsy moth sprays, herbicides, and inappropriate and/or overuse of fire in prescribed burn programs. Factors such as those above are probably often the ultimate causes of decline via a breakdown of metapopulation functions. Isolated colonies are more susceptible to localized extirpations due to threats and local catastrophic events (severe weather, natural fires, etc). This species is generally highly dependent on management, either on preserves (usually prescribed burning) or in active pastures which are probably its best habitats (Powell and Kindscher 2007). This species is most secure near the southern limit of its range. Habitats in the northern limit are more scarce and fragmented, therefore, global warming is an anticipated threat, since losses in the southern part of its range would not be compensated by expansion farther north. Note that Pennsylvania is both on the eastern and northern edge of the regal fritillary’s range. In the CCVI index ‘northern edge of range’ was selected for the ‘Relation of Species' Range to Assessment Area’ since this appears to be the more important aspect of its range in light of climate change.

Main factors Contributing to Vulnerability:

The climate change vulnerability rating of Not Vulnerable/Presumed Stable resulted from a blending of competing factors that could increase or decrease this species’ sensitivity to climate change. For example, the regal fritillary does not require pristine or extremely specialized habitats in Pennsylvania, but they are fairly dependent upon humans to create and maintain suitable grassland habitat. Vulnerability is increased because regal fritillary caterpillars are limited to a diet of violets and the long-lived adults require a steady seasonal progression of nectar sources. However, vulnerability is decreased because the regal fritillary is both a highly fecund butterfly, capable of laying thousands of eggs, and a strong flier, capable of dispersing to new habitats. For grassland species not adapted to fire (e.g., the regal fritillary lacks an underground resting stage), an alternate life history strategy is to have sufficient population reservoirs in adjacent unburned habitats and the ability to disperse so that it can recolonize newly burned areas.

Today, grassland species persist on increasingly small and isolated habitat ‘islands.’ They are more at risk of extirpation to any catastrophic event, including pesticide applications, a large fire, or poorly timed mowing. Climate change is predicted to cause increased summer droughts, which could lead to more frequent and severe fires (Shortle et al. 2009). This could increase the amount of suitable open grassland habitat this species needs and so is considered to potentially decrease vulnerability. An important consideration in this assessment is that the extent of the remaining regal fritillary population in Pennsylvania is well known. The population is carefully monitored and managed, and measures are taken to prevent the complete burning of its occupied habitat, which could be catastrophic for the population.

The region of Pennsylvania where the regal fritillary still occurred within the past 30 years has experienced average precipitation variation in the past 50 years, making populations neutrally vulnerable to future changes in precipitation. Microhabitat changes in seasonal temperatures and moisture levels are expected to be important, but the direction of effects (positive, negative, neutral) cannot be predicted at this time. Seasonal patterns such as cool wet springs can lead to increased vulnerability of populations to viral, bacterial, or fungal pathogens that are suspected to have played a role in the rapid decline of the regal fritillary in the eastern states (Weintraub pers. comm.). The genetic lineage (haplotype) of the last remaining metapopulation in Pennsylvania may have some natural resistance to such pathogens which may have contributed to its survival so far, but more research is needed.

Dispersal and movements: Some adult fritillaries will disperse away from home habitats, especially females. Fritillaries are long-lived, strong fliers easily capable of covering 1-6 kilometers in a day. Species of open habitats such as regal fritillary avoid entering wooded areas but they might fly over or around them. Developed areas cannot be assumed to be barriers as wandering adults have been observed visiting flower gardens in lightly urbanized areas (NatureServe 2008).

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Species: Northeastern Pine Zale (*Zale curema*)
Global Rank: G3G4
State Rank: S1
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Low

Habitat:

The northeastern pine zale is a moth of barrens habitats and pitch pine areas in eastern Pennsylvania. It is currently known from three sites in Pennsylvania, two in the southeast and one in the northeast. Northeastern pine zale can utilize a variety of pitch pine barrens, woodlands, and pine-oak forests. The larval food plant in Pennsylvania is pitch pine (*Pinus rigida*). The species is best collected at bait. More surveys are needed in pitch pine areas in appropriate habitat in the Appalachian Mountains and eastern Pennsylvania during the spring flight period (mid May to mid June).

Current Threats:

Fire is a potential threat to this species especially in June and July during the egg and active larval stages. However, fire is often necessary for maintaining open barrens. However, this species does not appear to require pristine pine barrens. It also does well in pitch pine woodlands or pine-oak forests.

Spraying to control gypsy moths may negatively affect the species depending on the life stage of the species, type of spray used, timing of spraying activities, and number of applications. Two sprays, diflubenzuron (trade name Dimilin) and *Bacillus thuringiensis* var. *kurstaki* (Btk), are commonly used for gypsy moth control. Diflubenzuron is a broad-spectrum insecticide universally toxic to several types of arthropods including butterfly and moth caterpillars. Diflubenzuron could be more problematic to northeastern pine zale larvae because it persists on treated foliage until leaf drop in the fall. When leaves fall on the forest floor, the chemical becomes part of the leaf litter and may enter forest streams via surface runoff (Butler 1998). Btk is commonly used in Pennsylvania to control gypsy moths because it targets butterfly and moth caterpillars and is not toxic to a wider spectrum of arthropods outside of the Order Lepidoptera. Btk also does not persist in the environment since it breaks down within ten days (Butler 1998).) Where gypsy moth outbreaks are particularly severe and pitch pines are expected to be completely defoliated, the loss of host plants would be more detrimental than the use of Btk (Schweitzer 1995). A small percentage of larvae would be at risk in May when spraying occurs, with greater mortality expected with use of Dimilin than with Btk.

Main factors Contributing to Vulnerability:

The main factors contributing to climate change vulnerability are large scale changes in the amount and seasonality of soil moisture, the northeastern pine zale's restricted range in Pennsylvania, and its dependence on one host plant during the larval stage.

Anthropogenic barriers (agricultural, residential, and urban development) block dispersal to the north for the populations in southeastern Pennsylvania. Mitigating factors include the ability of adults to disperse relatively easily through suitable habitat, and the species is not restricted to particularly specialized habitats.

The regions of Pennsylvania where northeastern pine zale occurs have experienced lower than average precipitation variation in the past 50 years, making populations more vulnerable to future changes in precipitation. Increased summer soil droughts are predicted by climate models, and could lead to an increase in the amount and severity of forest fires (Shortle et al. 2009). The widespread burning of occupied habitats at the wrong time of year (June-July) could be devastating to local populations, especially those located in smaller habitat patches such as the serpentine barrens of southeastern Pennsylvania. Fire-related mortality at this time of year would be expected to be near 100% because the eggs and/or actively feeding larvae are very vulnerable to fire. The pupal stage takes place on the ground in humus and leaf litter and so is also very vulnerable to fire. Nevertheless, forest fires are a process that helps to maintain northeastern pine zale habitat. Small, patchy, controlled burns can be a useful tool in barrens habitat management.

Dispersal and movements: NatureServe assigned northeastern pine zale to the ‘Forest, Woodland and Shrub Noctuidae’ moth group. Moths assigned to this group are moderately to very strong fliers and many live from a week to a month as adults. These moths are typically found in extensive tracts of appropriate habitat but they can persist in somewhat fragmented patches. Within suitable habitats, these species are usually widespread and are likely able to traverse distances up to 10 km. Suitable habitat for northeastern pine zale, which feeds solely on pitch pine, should have a food plant density of three mature trees per hectare (NatureServe 2008).

Moths in the Forest, Woodland and Shrub Noctuidae group can be expected to travel and disperse through marginal woodland and scrub habitats. However, these species would not be expected to travel more than 2 km across unsuitable habitats, such as treeless landscapes, or residential or urban areas that have trees but not the appropriate food plant or other essential features (NatureServe 2008).

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Species: Frosted Elfin (*Callophrys irus*)
Global Rank: G3
State Rank: S1S2
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat (adapted from NatureServe 2008):

Historically the natural habitat for this species was grassy openings dominated by *Andropogon* spp. and burned areas in oak barrens and savannas with sandy/rocky soils. Today, the species occurs mostly in open habitats created and maintained by human activities such as powerline and railroad right of ways, along sand or gravel roads in dry woods and barrens habitats, and around rock outcrops and old gravel pits. Active roadways with host plants are not good habitat because annual spring mowing will kill the larvae, and vehicle traffic will drive off adults.

Nearby tree cover is an important habitat component, because it provides shelter from the wind and sun. Adult males tend to congregate in open grassy areas with food plants in cool to moderate weather where they defend grass clumps, but they often move to shady woodland edges at about 82°F.

Frosted elfins occur in two population types, one with caterpillars that feed on lupine (*Lupinus perennis*), and the other with caterpillars that feed on wild indigo (*Baptisia tinctoria*). All populations in Pennsylvania are thought to be wild indigo feeders, even if lupine is also available. Adults are usually found very close to wild indigo plants (e.g., within 20 m).

Current Threats (adapted from NatureServe 2008):

The main threats in Pennsylvania are loss of wild indigo to natural succession of open habitats and deer herbivory, plus habitat fragmentation and destruction. Overuse of prescribed burning (in extent and/or frequency) may eradicate populations. Gypsy moth spraying with *Bacillus thuringiensis* var. *kurstaki* (Btk) is a threat, especially to smaller populations. A strong population could probably survive one Btk application since larval emergence is staggered and later ones would not be exposed. Applications of more persistent toxins like Diflubenzuron are more likely to eradicate an occurrence (Schweitzer, 2004). Most frosted elfin populations are now dependent upon human management to maintain their habitat. This makes populations vulnerable to sudden changes in management practices, such as a switch from winter mowing to disking and herbiciding.

Frosted elfins seem to tolerate dormant season or late summer mowing very well and will colonize wildfire scars once the host plant moves in. However, frequent prescribed burning can have deleterious effects according to research on the lupine feeder conducted by Ann Swengel (1998). Little is known about the role of fire in the ecology of the wild indigo feeder. Larvae feeding on wild indigo plants and chrysalids hibernating in loose cocoons in the litter beneath host plants are both vulnerable to fires.

Main factors Contributing to Vulnerability:

The main factors contributing to climate change vulnerability in the frosted elfin are changes in the amount and seasonality of soil moisture and the species dependence upon one host plant during the larval stage. A mitigating factor is the ability of adults to disperse relatively easily through suitable habitat. The region of Pennsylvania where frosted elfin occurs (currently or historically) has experienced slightly lower than average precipitation variation in the past 50 years, making populations somewhat vulnerable to future changes in precipitation. The impacts of development of alternative energy sources, and microhabitat changes in seasonal soil moisture levels and temperatures, are expected to be especially important for frosted elfin caterpillars, pupae, and the wild indigo host plant.

The impacts of climate change on frosted elfin microhabitats (positive, negative, or neutral) cannot be predicted at this time without more data. This species appears to be adapted to warmer microhabitats, but details on the optimal range and seasonality of soil temperature and moisture for the development of frosted elfin pupae overwintering in the leaf litter are unknown. Increased summer soil droughts are predicted by climate models, and could lead to an increase in the amount and severity of forest fires (Shortle et al. 2009). Forest fires could create new habitat and reset habitat succession thus creating frosted elfin habitat. However, fire-related mortality over occupied habitats during burns would be expected near 100% because the larvae and pupae are above the soil surface year-round (Allen 1997) and are therefore very vulnerable to fire. While frosted elfin is a rapid flier and good colonizer (Allen 1997), colonies tend to be small and suitable habitats are increasingly isolated in Pennsylvania. Therefore, loss of individual colonies may cause localized extinctions at sites that will not be recolonized naturally.

Infrastructure development supporting alternate energy sources such as wind energy and natural gas are likely to create many acres of disturbed land in forested habitats. Under appropriate soil conditions and with proper types and timing of vegetation management, these disturbed lands could become potential habitat for frosted elfins. The species could be encouraged with plantings of wild indigo and other native nectar plants. Right-of-way corridors could then play an important role in providing habitat and promoting species dispersal.

These developments would require considerable investment in planning and resources to maximize the potential benefit for this species. Therefore, the impacts of predicted land use changes could range from somewhat decreasing to somewhat increasing vulnerability. Infrastructure development could easily have negative impacts as well. Broadcast herbiciding or disking of rights-of-ways would eliminate their usefulness as habitat corridors. Undocumented populations and currently unoccupied (but ultimately recolonizable) habitat could be inadvertently destroyed in right-of-way development.

Pre-development surveys for potential habitat would be needed to avoid destruction of occupied or potentially occupied habitats.

Dispersal and movements (adapted from NatureServe 2008): There are no known published studies on the dispersal capabilities of frosted elfin. However, anecdotal evidence suggests that the species is regularly capable of dispersal of over a kilometer across open landscapes or along corridors. Frosted elfins tend to occur in small local populations in appropriate pockets of habitat. Populations located within several kilometers of one another are connected into larger metapopulations when adults are able to disperse through fairly open habitat or along linear rights-of-ways.

Note: This assessment is expected to be similar for the Persius Duskywing (*Erynnis persius*); Global Rank G5T1T3, State Rank S1; Caterpillar host plant wild indigo; Habitats include pitch pine-scrub oak barrens, scrubby ridgetops, or powerline right-of-ways within such settings with sandy-gravelly soils.

References:

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Species: Northern Barrens Tiger Beetle (*Cicindela patruela*)
Global Rank: G3
State Rank: S2S3
State Wildlife Action Plan: Immediate Concern Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Very High

<u>Habitat (adapted from Pearson et al. 2006; NatureServe 2008):</u>

The northern barrens tiger beetle is specific to sandy/coarse gravel or eroding sandstone substrates throughout its range. It may have more specialized habitat requirements within a given geographic region. The associated plant community is usually pine barrens or open mixed or deciduous (mainly oak) woodlands and shrublands. The beetle utilizes patches of open ground, such as along trails, on outcrops, scree or talus slopes, or on ridge summit openings dominated by lichens and dry mosses. In much of its range, the northern barrens tiger beetle is associated with coarse grained sand or eroding sandstone. Larvae construct burrows in open patches of stabilized and compact sandy soils, often associated with mosses, lichens, and other low vegetation. Populations are typically scattered and low density. Small individual colonies can occur on sites less than a hectare, but populations typically function as metapopulations across forested landscapes of 100 or more hectares with scattered patches of suitable habitat.

<u>Current Threats (adapted from NatureServe 2008):</u>

The main threat to this species is habitat destruction due to development, deforestation, and fire suppression (fire suppression and ecological succession may eliminate some habitats). At the same time, human activities (e.g., soil disturbance) may be vital for the creation of suitable habitat. Most authors mention that this species will occupy little used forest roads. Heavy use of these by ATVs or other motorized vehicles, and improvements to remote sandy roads on state lands could impact occurrences in some locations. More research is needed to determine the extent to which sandy roads are breeding areas, and the threat potentially posed by the use and maintenance of such roads.

<u>Main factors Contributing to Vulnerability:</u>

The main factors contributing to climate change vulnerability are large scale changes in the amount and seasonality of soil moisture and the physical habitat specificity of the northern barrens tiger beetle. Main mitigating factors are the ability of adults to disperse relatively easily through suitable habitat and the likelihood that natural disturbances (e.g., fire) and alternative energy development (e.g., natural gas infrastructure) will increase the amount of potential habitat for this species.

The regions of Pennsylvania where the northern barrens tiger beetle is known to occur has experienced slightly lower than average precipitation variation in the past 50 years, making populations somewhat more vulnerable to future changes in precipitation. Increased summer soil droughts are predicted by climate models and could lead to an increase in the amount and severity of forest fires (Shortle et al. 2009). This species is fairly well adapted to fire, and forest fires could benefit the species by creating new habitat and resetting succession. Adults emerge in the spring (typically late April to June) and again from mid August into September (late summer eclosions may be sporadic). Adults may be able to escape fires, and the larval life cycle is two years so that there are always larvae present and somewhat protected in burrows in the substrate (Pearson et al. 2006; NatureServe 2008). For these reasons, the northern barrens tiger beetle was ranked as ‘Somewhat less vulnerable’ in regards to reliance on a specific disturbance regime (fire) that is expected to increase in frequency, severity, or extent with climate change and would increase the species’ habitat quality.

Right-of-way infrastructure supporting alternate energy sources such as wind energy and natural gas may create many acres of disturbed land in forested habitats. Under certain conditions of soil, bedrock, moisture, and aspect, newly disturbed lands could become potential habitat for the northern barrens tiger beetle. Recent collection sites indicate that disturbed right-of-ways such as powerline rows, logging access roads and pipelines, oil and gas well openings, etc. can provide suitable habitat. Right-of-ways may assist the species in finding suitable disturbed sites as they become naturalized with mosses, lichens, and other low vegetation. Maintaining a forest matrix around disturbed areas is important, as is preventing ATVs and other vehicular traffic from utilizing access roads and disturbed areas. Frequent road usage and improvement could be harmful (NatureServe 2008), particularly to the larvae as they develop in burrows in sandy soils. Infrastructure development may not require considerable planning and management in order to maximize the potential benefit for this species, therefore predicted impact of land use changes was ranked as ‘Decrease Vulnerability’.

Changes in temperature and precipitation, moisture, or hydrological regime on a microhabitat scale are certain to be important factors for predicted sensitivity. This species is well adapted to hot microhabitats (eroded sandstone clearings), but details on the optimal range and seasonality of soil temperature and moisture for the development of larvae and pupae are not known. For the CCVI the microhabitat temperature and moisture were ranked as ‘Unknown’ which leads to an overall rating of Presumed Stable/Not Vulnerable. Selecting ‘Somewhat Increases Vulnerability’ for these two factors did not lead to a change in overall vulnerability rating.

Dispersal and movements (adapted from NatureServe 2008): Quantitative information on tiger beetle movements in barrens and shrubland habitats are few and mostly anecdotal. However, tiger beetles of these habitats are known to be good colonizers capable of flying a few kilometers (apparently sometimes at night).

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Species: Fingered Lemmeria Moth (*Lemmeria digitalis*)
Global Rank: G4
State Rank: S2S4
State Wildlife Action Plan: High-level Concern Species - Responsibility Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

The fingered lemmeria moth is encountered in wetland habitats in northwest Pennsylvania. The caterpillar food plant is unrecorded. The only species in the genus, fingered lemmeria moth is related to other noctuid genera that bore in the stems and rootstocks of various herbaceous plants, grasses, and sedges.

This species is currently known from the Allegheney National Forest and two additional counties in northwestern Pennsylvania. This moth appears to be very rare throughout its range. A number of recent records in Pennsylvania wetlands suggest that Pennsylvania may be a stronghold for fingered lemmeria moth and it was accordingly designated as a Pennsylvania Responsibility Species (Rawlins 2007).

Current Threats:

Threats cannot be fully assessed until more is known about the life history of this species. Typical threats for lepidoptera are habitat loss and fragmentation, fires, high deer populations and herbivory, and gypsy moth control.

Main factors Contributing to Vulnerability:

The main factors contributing to climate change vulnerability are large scale changes in the amount and seasonality of soil moisture, association with cooler and more northern localities in the commonwealth, and its likely dependence on one or a few host plants during the larval stage. Mitigating factors include the ability of adults to disperse relatively easily through suitable habitat; the species is not restricted to particularly specialized habitats, and it may be able to shift its range in response to climate change.

The regions of Pennsylvania where fingered lemmeria moth occurs have experienced lower than average precipitation variation in the past 50 years, making populations somewhat more vulnerable to future changes in precipitation.

The impacts of development of alternative energy sources are expected to be important especially as it relates to population dynamics and the health of populations of its food plant. Right-of-way infrastructure supporting alternate energy sources such as wind energy and natural gas are expected to further fragment many acres of land in forested habitats. There may be other factors that affect the distribution of this moth, and metapopulation dynamics are likely a component.

Dispersal and movements: NatureServe assigned fingered lemmeria moth to the 'Papaipema and related borers' moth group. Typically these are sedentary moths that are usually found within 10 m of food plant patches. Females appear to be more dispersive than males and tend to disperse after laying some eggs at the natal site. Female Papaipema and some related genera have been found to disperse at least several kilometers (NatureServe 2008).

<u>References:</u>

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Species: Red-banded Hairstreak (*Calycopis cecrops*)
Global Rank: G5
State Rank: S4 (State rank changed in 2002 from S2S3 to S4)
Climate Change Vulnerability: Not Vulnerable/Increase Likely
Confidence: Very High

Habitat (adapted from Allen 1997; NatureServe 2008):

The red-banded hairstreak is found in a variety of semi-open brushy habitats and forest edges. The species will utilize abandoned farms and old fields, hedgerows, right-of-ways, and occasionally yards with food plants. The caterpillars feed on a wide variety of detritus (rotting leaves) especially preferring detritus from sumacs (*Rhus* spp.) but also reported to feed on detritus from the *Croton* spp. and *Myrica* spp. Adults are seen mostly in the open and on edges in spring, but will move into the deep shade of forests during hot summer weather (observations by D. Schweitzer in New Jersey). Adults commonly visit gardens to nectar.

Current Threats:

Loss of habitat due to natural succession of habitats and conversion of old fields and other fallow habitats for other land uses such as active agriculture and development.

Main factors Contributing to Vulnerability:

This species was formerly limited in Pennsylvania by an intolerance of overwintering larvae to minimum winter temperatures. This species appears to be having greater overwintering success over the past decade, particularly in the south-east corner of the state. Throughout its range, the species is widespread and adapted to disturbed habitats. While it requires successional habitats, it is not closely tied to fire-maintained natural communities. Development of infrastructure for alternate energy sources (e.g., wind and natural gas) is expected to create additional successional habitat for red-banded hairstreaks and their favored and abundant host plant (sumacs). The species is a strong colonizer/disperser and is capable of migrating short distances in response to environmental variables. These characteristics will help the red-banded hairstreak colonize new habitats to the north as temperatures become suitable for overwintering larvae.

Dispersal and movements: Pennsylvania has resident populations (David Wright pers. comm.), which are augmented by additional individuals moving in a south-north direction as summer progresses. The red-banded hairstreak is reported to migrate at least short distances (Pyle 1981; Brock and Kaufman 2003), with heavier movement some years (Kessler 2000; CBA 2007) likely in response to environmental conditions.

The following paragraph is summarized from an email correspondence from David Wright of August 22, 2000, and provides more insight into the expansion of the red-banded hairstreak into Pennsylvania:

Alan Gregory's collection of the red-banded hairstreak at Conyngham, Pennsylvania (near Hazleton in Luzerne County, Ridge and Valley Province) is the northernmost extent this migratory species has been found in Pennsylvania. Before 1999, the red-banded hairstreak was rare in southeastern Pennsylvania above the Fall Line (e.g., outside of the coastal plain). Philadelphia and southward usually would get a straggler or two in late summer/fall. In May 1999, David Wright started seeing red-banded hairstreaks in Lansdale (a northern suburb of Philadelphia in Montgomery County, Piedmont Province). Wright saw them throughout the summer until the last specimen was found on September 15. The winter of 1999 was relatively mild and the year 2000 spring populations were well stocked with progeny from the previous year's recruitment. The push northward is apparently underway. Interestingly, the famous old collector, Max Rothke of Scranton (Luzerne Co.), never caught a red-banded hairstreak in 30 years of collecting. Identifications by experienced butterfly watchers and collectors are reliable, there are no 'look-alike' species in the north-east and it is not part of a cryptic species complex.

References:

Brock, J.P. and K. Kaufman. 2003. Butterflies of North America. Houghton Mifflin Company, New York.

Connecticut Butterfly Association (CBA). 2007. Field Notes reporting observations from August 1 2007 through December 31 2007. Accessed online at [http://ctbutterfly.org/field%20notes/FLDNTE23.html].

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MAMMALS

Species: Eastern Small-footed Bat (*Myotis leibii*)
Global Rank: G3
State Rank: S1B, S1N
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Low

<u>Habitat:</u>

The eastern small-footed bat usually occurs in mountainous regions, in or near deciduous or evergreen forests. Warm season roosts include caves, coal mines, buildings, bridges, and spaces in rocks and tree cavities. Winter hibernacula include caves and mine tunnels (NatureServe 2010). This species has been found in very cold caves and can tolerate lower temperatures than other bat species (Whitaker and Hamilton 1998). The eastern small-footed bat occurs from northern New England through New York to North Carolina, Tennessee, and northern Georgia, Alabama, and Mississippi west into Arkansas and southeastern Oklahoma (Whitaker and Hamilton 1998). Within the known range, distribution is spotty and the bat is considered rare to uncommon (Choate et al. 1994).

<u>Current Threats:</u>

The main threats to this species are destruction of habitat (both natural and artificial), white-nose syndrome, pollution (especially water), and human disturbance during hibernation (NatureServe 2010).

<u>Main factors Contributing to Vulnerability Rank:</u>

Predicted impact of land use changes designed to mitigate against climate change: The development and operation of wind farms may negatively affect bat populations.

Predicted micro sensitivity to changes in temperature: The species shows a strong preference for local microsites/microhabitats (caves) toward the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the species range in Pennsylvania, the species has experienced slightly lower than average precipitation variation in the past 50 years.

Physical habitat specificity: Eastern small-footed bat is highly specialized in its habitat use for winter hibernacula (caves and mines).

References:

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Whitaker, J.O. and W.J. Hamilton (editors). 1998. Mammals of the eastern United States. Third Edition. Cornell University Press, Ithaca, New York. 583 pp.

Species: Allegheny Woodrat (*Neotoma magister*)
Global Rank: G3G4
State Rank: S3
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species/Pennsylvania Threatened Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Very High

Habitat:

The Allegheny woodrat once inhabitated a larger range extending from southwestern Connecticut west to Indiana and south to central Alabama. The Allegheny woodrat is now extirpated from Connecticut and New York with documented population declines in the remaining northern states. Less is known about their status in southern states due to a lack of recent surveys (Butchkoski 2010). The Allegheny woodrat typically uses rocky cliffs, talus slopes, and caves dispersed across primarily forested landscapes (Merritt 1987; Castleberry et al. 2001; Castleberry et al. 2002).

Current Threats:

Major threats to the species include loss of habitat and population isolation (NatureServe 2010). Other threats that have been attributed to the decline of the species include loss of American chestnut as an important food source, gypsy moth infestations that damage oak trees resulting in a reduction in hard mast, fatal infections by raccoon roundworm parasite, and land use alterations resulting in increased predation pressure (Balcom and Yahner 1996; Butchkoski 2010).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural and anthropogenic barriers: Although suitable habitat is available within and north of its current range in Pennsylvania, the species is limited in its ability to disperse due to landscape fragmentation, agricultural fields, and urbanization.

Dispersal and movements: The species is limited in how far it can move between rocky habitat patches. Castleberry et al. (2001) found that Allegheny woodrats moved an average of 152 m within their home range.

Physical habitat specificity: The species is moderate to highly specialized in its physical habitat requirements. The Allegheny woodrat typically uses rocky cliffs, talus slopes, and caves dispersed across primarily forested landscapes (Merritt 1987; Castleberry et al. 2001; Castleberry et al. 2002).

References:

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Species: Appalachian Cottontail (*Sylvilagus obscurus*)
Global Rank: G4
State Rank: SNR
State Wildlife Action Plan Priority: High-level Concern Species
CCVI Rank: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

Appalachian cottontail is associated with dense cover of heaths, particularly blueberry and laurel, and with conifers at the higher elevations in the Appalachians (Whitaker and Hamilton 1998). The species has a discontinuous distribution in the Appalachians from southwest of the Hudson River, Pennsylvania, Maryland, West Virginia, Virginia, and Kentucky south to Tennessee, North Carolina, South Carolina, Georgia, and Alabama (Whitaker and Hamilton 1998).

Current Threats:

The main threats to this species are alteration of habitat by human activity and the range expansion of the eastern cottontail. Also, populations are small, scattered, and isolated (NatureServe 2010).

Main Factors Contributing to Vulnerability Rank:

Although Appalachian cottontail is at its northern range in Pennsylvania and prefers cooler microsites dominated by mostly heath species, the CCVI does not suggest that abundance and/or range extent within Pennsylvania will change (increase/decrease) substantially by 2050. However, actual range boundaries may change. The CCVI suggests that abundance could shift within the defined range boundaries. The species is capable of dispersing long distances and has a low dependence on processes likely to be altered in the short term by climate change.

References:

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Whitaker, J.O. and W.J. Hamilton (editors). 1998. Mammals of the eastern United States. Third Edition. Cornell University Press, Ithaca, New York. 583pp.

Species: Snowshoe Hare (*Lepus americanus*)
Global Rank: G5
State Rank: S3S4
State Wildlife Action Plan Priority: Maintenance Concern Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: High

Habitat:

The snowshoe hare is most common in mountainous sections of the northern half of Pennsylvania. In the northwestern portion of the state, it inhabits high ridges marked by mountain laurel and rhododendron. In the Poconos, the snowshoe hare favors mature forests with swamps and bogs at high elevations. In the Allegheny Mountains, the species is found on steep, heavily forested slopes of hemlock, rhododendron, and mountain laurel with a dense, brushy understory (Merritt 1987).

Current Threats:

The primary threats to this species are loss of habitat due to maturing forests and competition with large deer populations for food.

Main Factors Contributing to Vulnerability Rank:

Although the range of the snowshoe hare in Pennsylvania may be more limited to the cooler elevations found in the northern tier of the state and the species is adapted to winters with snow cover, the CCVI rank indicates that available evidence does not suggest that abundance and/or range extent within Pennsylvania will change substantially by 2050. The species is capable of dispersing long distances and has a low dependence on processes likely to be altered by climate change. However, the range shift of other competing species such as Appalachian cottontail due to climate change effects could potentially negatively impact this species.

References:

Merritt, J.E. 1987. Guide to the mammals of Pennsylvania. University of Pittsburgh Press, Pittsburgh, PA.

MOLLUSKS

Species: Eastern Pearlshell (*Margaritifera margaritifera*)
Global Rank: G4
State Rank: S1
State Wildlife Action Plan Priority: High-level Concern Species
CCVI Rank: Extremely Vulnerable
Confidence: Very High

Habitat (adapted from NatureServe 2010):

Eastern pearlshells are generally found in cold, nutrient-poor, unpolluted trout streams and smaller rivers with moderate flow rates. Benthic substrate is usually sand, fine gravel, or a sand-gravel mix where mussels can bury themselves (Spoo 2008). This species has a circumboreal distribution in northern Europe, eastern North America, and Eurasia. Its range includes the arctic and temperate regions of western Russia, westwards through Europe to the north-eastern seaboard of North America and southwards to the Iberian peninsula and "central" Europe. In North America, it is distributed from Newfoundland and Labrador down to Pennsylvania (Burch 1975) and Delaware and west to the Appalachian mountains (Ziuganov et al. 1994).

Current Threats:

Impacts to water quality from coal mining have eradicated the eastern pearlshell from all but a very few locations in Pennsylvania. Other threats include degradation of water quality, alteration of pH, eutrophication, and temperature increases in streams (PA Bulletin, Doc # 05-1675).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to anthropogenic barriers: Several dams are located upstream of the few known locations of this species in Pennsylvania and will likely hinder possible establishment of metapopulations upstream of known occurrences (PA Bulletin, Doc # 05-1675).

Predicted impact of land use changes designed to mitigate against climate change: Natural gas extraction in the upper Delaware region of Pennsylvania may negatively impact river water quality.

Dispersal and movement: As adults, eastern pearlshells are mostly non-migratory with only limited vertical movement and possibly passive movement due to flood events (NYNHP 2010).

Predicted micro sensitivity to changes in temperature: Since eastern pearlshells inhabit cold water trout streams, temperature increases due to climate change will likely alter habitat quality.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a very small precipitation variation in the past 50 years.

Dependence on specific disturbance regime likely to be impacted by climate change: More intense flooding events, likely associated with climate change in Pennsylvania, may affect eastern pearlshell populations by altering water/habitat quality (e.g., increased siltation).

Dependence on other species for propagule dispersal: Eastern pearlshells depend on a few salmonid fish to serve as glochidial hosts (Spoo 2008).

<u>References:</u>

Burch, J.B. 1975. Freshwater unionacean clams (Mollusca: Pelecypoda) of North America. Malacological Publications: Hamburg, Michigan. 204 pp.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

New York Natural Heritage Program. 2010. NYNHP Conservation Guide – Eastern Pearlshell.

PA Bulletin, Doc# 05-1675.

Spoo, A. 2008. The pearly mussels of Pennsylvania. Coachwhip Publications. Landisville, Pennsylvania. 210pp.

Ziuganov, V., A. Zotin, L. Nezlin, and V. Tretiakov. 1994. The Freshwater Pearl Mussels and Their Relationships with Salmonid Fish. VNIRO Publishing House: Moscow, Russia. 104 pp.

Species: Dwarf Wedgemussel (*Alasmidonta heterodon*)
Global Rank: G1G2
State Rank: S1
State Wildlife Action Plan Priority: Immediate Concern Species
CCVI Rank: Highly Vulnerable
Confidence: Very High

Habitat:

Dwarf wedgemussels generally live in creek and river bottoms where sand is a component of the substrate (e.g., muddy sand, sand, sand and gravel bottoms), the current is slow to moderate, and there is little silt deposition (USFWS 1993). This species is discontinuously distributed in the Atlantic coast drainages from Maine to North Carolina (NatureServe 2010).

Current Threats:

Major threats leading to the decline of dwarf wedgemussel include impoundments, pollution, sedimentation, competition from exotic species, population-related problems, and construction projects (USFWS 1993).

Main Factors Contributing to Vulnerability Rank:

Predicted impact of land use changes designed to mitigate against climate change: Natural gas extraction may alter the water quality of the Delaware River.

Dispersal and movement: As adults, the dwarf wedgemussel is mostly non-migratory with only limited vertical movement and possibly passive movement due to flood events (NYNHP 2010).

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a very small precipitation variation in the past 50 years.

Dependence on specific disturbance regime likely to be impacted by climate change: More intense flooding events, likely associated with climate change in Pennsylvania, may affect dwarf wedgemussel populations by altering water/habitat quality of rivers and streams (e.g., increased silt load).

Dependence on other species for propagule dispersal: Dwarf wedgemussel depends on a few fish (Johnny darter, tessellated darter, and mottled sculpin) to serve as glochidial hosts (Spoo 2008).

References:

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

New York Natural Heritage Program. 2010. NYNHP Conservation Guide – Eastern Pearlshell.

Spoo, A. 2008. The pearly mussels of Pennsylvania. Coachwhip Publications. Landisville, Pennsylvania. 210pp.

U.S. Fish and Wildlife Service. 1993. Dwarf Wedgemussel (*Alasmidonta heterodon*) recovery plan. U.S. Fish and Wildlife Service, Hadley, Massachusetts. 52 pp.

Species: Clubshell (*Pleurobema clava*)
Global Rank: G2
State Rank: S1
State Wildlife Action Plan Priority: Immediate Concern Species
CCVI Rank: Highly Vulnerable
Confidence: Moderate

<u>Habitat (adapted from NatureServe 2010):</u>

Clubshells are generally found in clean, coarse sand, and gravel in the runs of medium-sized to large rivers (Spoo 2008). Historically, the species was distributed across nine states in the Wabash, Ohio, Kanawha, Kentucky (Danglade 1922; Clarke 1987), Green, Monongahela, and Allegheny rivers and their tributaries. It has been recorded from most of the tributaries in Kentucky, Illinois, Indiana, and Ohio, as well as from more isolated systems in Michigan, Pennsylvania, and West Virginia. Records from Nebraska, Minnesota, and Iowa (Simpson 1900) are erroneous (USFWS 1994).

<u>Current Threats:</u>

Major threats leading to the decline of clubshells include siltation, impoundment, in-stream sand and gravel mining, pollutants, and competition by non-native mussels (USFWS 1994).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to natural barriers: In Pennsylvania, the species is limited to the Allegheny River drainage.

Distribution relative to anthropogenic barriers: Dams are located upstream of some locations of this species in the Allegheny River that could possibly hinder the establishment of new populations upstream from known occurrences.

Predicted impact of land use changes designed to mitigate against climate change: Waterways where the species occurs may be suitable for future placement of hydropower plants thus potentially blocking upstream migration. Natural gas extraction may alter water quality.

Dispersal and movement: As adults, clubshells are mostly non-migratory with only limited vertical movement and possibly passive movement due to flood events (NYNHP 2010).

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a slightly lower than average precipitation variation in the past 50 years.

Dependence on specific disturbance regime likely to be impacted by climate change: More intense flooding events, likely associated with climate change in Pennsylvania, may affect clubshell populations by altering water/habitat quality of rivers and streams (e.g., increased silt load) and/or fragmenting populations.

Dependence on other species for propagule dispersal: Clubshells depend on a few fish (central stoneroller, striped shiner, logperch, and blacksided darter) to serve as glochidial hosts (Spoo 2008). "Migration" may occur in the glochidial stage when juveniles are transported by host fish but this distance is probably less than 10 km (NatureServe 2010).

References:

Clarke, C.F. 1987. The freshwater naiads of Ohio, Part V Wabash River drainage of Ohio. Malacology Data Net, 2(1/2): 19-37.

Danglade, E. 1922. The Kentucky river and its mussel resources. U.S. Bureau of Fish. Doc. (934):1-8.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

New York Natural Heritage Program. 2010. NYNHP Conservation Guide – Eastern Pearlshell.

Simpson, C.T. 1900. Synopsis of the naiades, or pearly freshwater mussels. Proceedings of the United States National Museum, 22(1205): 501-1044.

Spoo, A. 2008. The pearly mussels of Pennsylvania. Coachwhip Publications. Landisville, Pennsylvania. 210pp.

U.S. Fish and Wildlife Service (USFWS). 1994. Clubshell (*Pleurobema clava*) and northern riffleshell (*Epioblasma torulosa rangiana*) recovery plan. U.S. Fish and Wildlife Service. Hadley, Massachusetts. 58pp.

Species: Rayed Bean (*Villosa fabalis*)
Global Rank: G2
State Rank: S1
State Wildlife Action Plan Priority: Immediate Concern Species
CCVI Rank: Highly Vulnerable
Confidence: Moderate

Habitat:

Rayed beans occur in fine sand in the shallow areas of medium-sized to large rivers (Spoo 2008). Rayed beans were historically known from 106 streams, lakes, and some man-made canals in 10 states and 3 service regions. The species occurred in parts of the upper and lower Great Lakes system, and throughout most of the Ohio and Tennessee River systems (NatureServe 2010).

Current Threats:

Major threats leading to the decline of rayed beans include habitat degradation and loss due to dam construction and stream channelization, siltation, pollution, and introduction of exotic zebra mussels (NatureServe 2010).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to anthropogenic barriers: Dams are located upstream of some locations of this species that could hinder the establishment of new populations upstream from known occurrences.

Predicted impact of land use changes designed to mitigate against climate change: Natural gas extraction in this region may alter water quality.

Dispersal and movements: As adults, rayed beans are mostly non-migratory with only limited vertical movement and possibly passive movement due to flood events (NYNHP 2010

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Dependence on specific disturbance regime likely to be impacted by climate change: More intense flooding events, likely associated with climate change in Pennsylvania, may affect rayed bean populations by altering water/habitat quality (e.g., increased siltation)

Dependence on other species for propagule dispersal: Rayed beans depend on a few fish (darter species) to serve as glochidial hosts (Spoo 2008).

References:

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

New York Natural Heritage Program. 2010. NYNHP Conservation Guide – Eastern Pearlshell.

Spoo, A. 2008. The pearly mussels of Pennsylvania. Coachwhip Publications. Landisville, Pennsylvania. 210pp.

Species: Northern Riffleshell (*Epioblasma torulosa rangiana*)
Global Rank: G2
State Rank: S2
State Wildlife Action Plan Priority: Immediate Concern Species
CCVI Rank: Highly Vulnerable
Confidence: Very High

Habitat (adapted from NatureServe 2010):

Northern riffleshell occurs in packed sand and gravel in riffles and runs in medium-sized to large rivers (USFWS 1994; Spoo 2008). As with most naiads, its current range is a remnant of its former distribution. The species is currently extant in only seven streams; the Green River in Kentucky, French and LeBoeuf creeks and the Allegheny River in Pennsylvania, the Detroit River in Michigan (possibly extirpated), and Big Darby Creek in Ohio (USFWS 1993), and recently discovered in at least one additional river in Ontario (Metcalfe-Smith et al. 1998).

Current Threats:

Major threats leading to the decline of northern riffleshell include siltation, impoundment, in-stream sand and gravel mining, pollutants, and competition by non-native mussels (USFWS 1994).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to anthropogenic barriers: Dams are located upstream of some locations of this species that could hinder the establishment of new populations upstream from known occurrences.

Predicted impact of land use changes designed to mitigate against climate change: Natural gas extraction in this region may alter water quality.

Dispersal and movements: As adults, northern riffleshells are mostly non-migratory with only limited vertical movement and possibly passive movement due to flood events (NYNHP 2010).

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Dependence on specific disturbance regime likely to be impacted by climate change: More intense flooding events, likely associated with climate change in Pennsylvania, may affect northern riffleshell populations by altering water/habitat quality (e.g., increased siltation)

Dependence on other species for propagule dispersal: Northern riffleshells depend on a few fish (brown trout and mottled sculpin) to serve as glochidial hosts (Spoo 2008).

References:

Metcalfe-Smith, J.L., G.L. Mackie, S.K. Staton, and E.L. West. 1998. Current status of rare species of freshwater mussels in southern Ontario. Triannual Unionid Report, 14: unpaginated.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

New York Natural Heritage Program. 2010. NYNHP Conservation Guide – Eastern Pearlshell.

Spoo, A. 2008. The pearly mussels of Pennsylvania. Coachwhip Publications. Landisville, Pennsylvania. 210pp.

U.S. Fish and Wildlife Service (USFWS). 1993. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Northern Riffleshell Mussel (*Epioblasma torulosa rangiana*) and the Clubshell Mussel (*Pleurobema clava*) (Final Rule). Federal Register, 58(13): 5638-5642.

U.S. Fish and Wildlife Service (USFWS). 1994. Clubshell (*Pleurobema clava*) and Northern Riffleshell (*Epioblasma torulosa rangiana*) recovery plan. U.S. Fish and Wildlife Service, Hadley, Massachusetts. 68 pp.

Species: Yellow Lampmussel (*Lampsilis cariosa*)
Global Rank: G3G4
State Rank: S3S4
State Wildlife Action Plan Priority: Immediate Concern Species
CCVI Rank: Highly Vulnerable
Confidence: Very High

<u>Habitat:</u>

Yellow lampmussels can be found in different aquatic habitats but appear to prefer the shifting sands downstream from large boulders in relatively fast flowing, medium to large streams and medium-sized rivers (Spoo 2008; NatureServe 2010). This species has a large geographic range, from Nova Scotia to Georgia in Atlantic drainages, and in the St. Lawrence River system westward to Ontario. While many historic occurrences are extirpated, the species still occurs in numbers in a few places, and the wide range is actually represented by several disjunct populations (NatureServe 2010).

<u>Current Threats:</u>

A major cause of the decline of freshwater mussels during the last century is the degradation and destruction of habitat by siltation, dredging, channelization, impoundments, and pollution (NYNHP 2010). Declining water quality and the introduction and establishment of zebra mussels have also contributed to the dramatic decline in mussel populations (Nalepa and Schloesser 1993; Metcalfe-Smith et al. 2000, 2003; Fisheries and Oceans Canada 2009).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to anthropogenic barriers: Dams are located upstream of some locations of this species that could hinder the establishment of new populations upstream from known occurrences.

Predicted impact of land use changes designed to mitigate against climate change: Natural gas extraction in this region may alter water quality.

Dispersal and movements: As adults, rayed beans are mostly non-migratory with only limited vertical movement and possibly passive movement due to flood events (NYNHP 2010).

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a slightly lower than average variation in the past 50 years.

Dependence on specific disturbance regime likely to be impacted by climate change: More intense flooding events, likely associated with climate change in Pennsylvania, may affect yellow lampmussel populations by altering water/habitat quality (e.g., increased siltation)

Dependence on other species for propagule dispersal: Yellow lampmussels depend on a few fish (yellow perch and white perch) to serve as glochidial hosts (Spoo 2008).

References:

Fisheries and Oceans Canada. 2009. Management Plan for the Yellow Lampmussel (*Lampsilis cariosa*) in Canada [Proposed]. Species at Risk Act Management Plan Series. Fisheries and Oceans Canada. 42pp.

Metcalfe-Smith, J.L., G.L. Mackie, J. DiMaio, and S.S. Taton. 2000. Changes over time in the diversity and distribution of freshwater mussels (Unionidae) in the Grand River, southwestern Ontaria. Journal of Great Lakes Research 26: 445-459.

Metcalfe-Smith, J.L., J. Di Maio, S.K. Staton, and S.R. De Solla. 2003. Status of the freshwater mussel communities of the Sydenham River, Ontario, Canada. American Midland Naturalist 150: 37-50.

Nalepa, T.F. and D. Schloesser. (Eds). 1993. Zebra mussels: biology, impacts, and control. CRC Press, Boca Raton, 810pp.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

New York Natural Heritage Program. 2010. NYNHP Conservation Guide – Yellow Lampmussel.

Spoo, A. 2008. The pearly mussels of Pennsylvania. Coachwhip Publications. Landisville, Pennsylvania. 210pp.

PLANTS

Species: White Fringed-orchid (*Platanthera blephariglottis*)
Global Rank: G4G5
State Rank: S2S3
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

<u>Habitat:</u>

White fringed-orchid grows in full sun or semi-shaded sphagnum bogs, acidic swamps, and other boggy areas. It is often found with cranberry and various sedges in a bed of sphagnum moss (PNHP 2007). The species is divided into two subspecies, one in the north (*P. blephariglottis*) and one in the south (*P. conspicua*). Pennsylvania marks the southern edge of the range for the northern subspecies which extends from Pennsylvania and New Jersey to northeastern Canada. In Pennsylvania, white fringed-orchid is limited to a few clusters of sites in the glaciated portions of the northeast and northwest and a few scattered sites at high elevations along the Allegheny Front (PNHP 2007).

<u>Current Threats:</u>

White fringed-orchid is somewhat threatened by land-use conversion, habitat fragmentation, and forest management practices. Other threats include alteration of hydrology, over-shading by woody growth, collection pressures (NatureServe 2010), and deer browsing.

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to natural barriers: Forests and mountains may limit the ability for this species to shift its range in response to climate change. Wetlands where this species is found tend to be isolated.

Dispersal and movement: Although seeds are dust-like in size, dispersal is thought to be a very limited distance (Machon et al. 2003).

Predicted micro sensitivity to changes in temperature: White fringed-orchid occurs in cooler microsites/microhabitats.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: White fringed-orchid is completely or almost completely dependent on wetland habitat that is likely highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Dependence on other species to generate habitat: The need for a mycorrhizal symbiont for germination and seedling establishment increases the vulnerability of this species to climate change.

Interspecific interactions: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of white fringed-orchid to climate change effects.

<u>Additional Information:</u>

This species is divided into two subspecies: one northern (in Pennsylvania) and one southern. For the northern subspecies, white fringed-orchid is at the southern end of its range and an increase in temperature may be detrimental. However, it is possible that the southern subspecies may move into the state.

<u>References:</u>

Arditti J. and A.K.A Ghani. 2000. Numerical and physical properties of orchid seeds and their biological implications. New Phytologist 145: 367-421.

Jersakova, J. and T. Malinova. 2007. Spatial aspects of seed dispersal and seedling recruitment in orchids. New Phytologist 176: 237-241.

Machon, N. P. Bardin, S.J. Mazer, J. Moret, B. Godelle, and F. Austerlitz. 2003. Relationship between genetic structure and seed and pollen dispersal in the endangered orchid *Spiranthes spiralis*. New Phytologist 157: 677-687.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Pennsylvania Natural Heritage Program. 2007. PNHP Fact Sheet – White Fringed-Orchid.

Species: Leafy Bog Aster (*Oclemena nemoralis*)
Global Rank: G5
State Rank: S1
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

Habitat:

Leafy bog aster is a boreal species found in northeastern North America with its western limit being the eastern Lake Superior region. The species' southern extent is northern Pennsylvania and New Jersey (NatureServe 2011). In Pennsylvania, leafy bog aster rarely occurs in sphagnum bogs and is only known from two sites in the northcentral portion of the state (Rhoads and Klein 1993; Rhoads and Block 2007).

Current threats:

Habitat loss and hydrological alteration are two major threats to this species.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Leafy bog aster is found in two isolated bogs in Pennsylvania that are surrounded by extensive forests that would likely serve as a barrier against movement to new locations.

Predicted micro sensitivity to changes in temperature: Leafy bog aster occurs in microsites/microhabitats towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a very small precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Leafy bog aster is dependent on a wetland habitat that may likely change as a result of climate change.

Interspecific interactions: Like most of the plants in the Asteraceae family, leafy bog aster probably requires mycorrhizal associations for survival (Hossler 2010).

References:

Hossler, K. 2010. Nutrient cycling and the role of arbuscular mycorrhizae in created and natural wetlands of central Ohio. Ph.D. dissertation, The Ohio State University.

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Pod-grass (*Scheuchzeria palustris*)
Global Rank: G5
State Rank: S1
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

Habitat:

Pod-grass is a circumboreal species in North America that ranges south to northern New Jersey, northern Pennsylvania, Wisconsin, Missouri, northern Idaho, and along the coast to northern California (NatureServe 2011). In Pennsylvania, pod-grass is found in a few cool, sphagnum bogs in the northeast and northwest portions of the state (Rhoads and Klein 1993; Rhoads and Block 2007). Pod-grass is typically confined to areas of permanent standing water and is usually part of the floating mat community (Tallis and Birks 1965).

Current Threats:

A main threat to this species is water fluctuations, even temporary ones can result in drying and mortality (NatureServe 2011).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Pod-grass is limited to a few isolated bogs in Pennsylvania that are surrounded by extensive forests that would likely serve as a barrier against movement to a new location.

Dispersal and movement: Little is known about the seed dispersal of this species but the large size of the seed would appear to preclude any effective long-distance dispersal (Tallis and Birks 1965).

Predicted micro sensitivity to changes in temperature: Pod-grass occurs in microsites/microhabitats towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Pod-grass is a wetland obligate species that is usually confined to areas of permanent standing water (Tallis and Birks 1965) and is highly sensitive to fluctuation in water levels (NatureServe 2011), a potential effect of climate change on the bogs where this species is found.

References:

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Tallis, J.H. and H.J.B. Birks. 1965. The past and present distribution of *Scheuchzeria palustris* L. in Europe. Journal of Ecology 53:287-298.

Species: Few-seeded Sedge (*Carex oligosperma*)
Global Rank: G5
State Rank: S2
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

Habitat:

Few-seeded sedge is a boreal species found in North America from Labrador and Newfoundland west to the Yukon Territory (but not British Columbia) and extends into the United States to include the Great Lakes states, New England states, New York, Pennsylvania, West Virginia, and North Carolina (NatureServe 2011). In Pennsylvania, few-seeded sedge rarely occurs at higher elevations in open, sphagnum bogs (Rhoads and Klein 1993; Rhoads and Block 2007).

Current Threats:

Habitat loss and habitat degradation (e.g., hydrological alteration) are two major threats to this species.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Few-seeded sedge is found in isolated wetlands in Pennsylvania that are surrounded by extensive forests that would likely serve as barriers against movement to new locations.

Predicted micro sensitivity to changes in temperature: Few-seeded sedge occurs in high elevation sites towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a slightly smaller than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Few-seeded sedge is an obligate wetland plant that has moisture requirements that will likely change as a result of climate change effects.

References:

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Fall Dropseed Muhly (*Muhlenbergia uniflora*)
Global Rank: G5
State Rank: S2
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

Habitat:

Fall dropseed muhly is a boreal species found in northeastern North America and British Columbia with its western limit in the United States being Minnesota. The species southern extent is northern Pennsylvania and New Jersey (NatureServe 2011). In Pennsylvania, fall dropseed muhly rarely occurs at higher elevations in marshes, bogs, and sandy roadsides (Rhoads and Klein 1993; Rhoads and Block 2007).

Current Threats:

Habitat loss and hydrological alteration are two major threats to this species.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Fall dropseed muhly is found in isolated wetlands in Pennsylvania that are surrounded by extensive forests that would likely serve as a barrier against movement to new locations.

Predicted micro sensitivity to changes in temperature: Fall dropseed muhly occurs in microsites/microhabitats towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Fall dropseed muhly is a wetland obligate plant that has moisture requirements that will likely change as a result of climate change effects.

Interspecific interactions: Like many of the plants in the Poaceae family, fall dropseed muhly probably requires mycorrhizal associations for survival (Hossler 2010).

References:

Hossler, K. 2010. Nutrient cycling and the role of arbuscular mycorrhizae in created and natural wetlands of central Ohio. Ph.D. dissertation, The Ohio State University.

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Horned Bladderwort (*Utricularia cornuta*)
Global Rank: G5
State Rank: S2
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

<u>Habitat:</u>

The species grows in shallow water or wet, peaty substrate in ponds, bogs, seepages, and along shorelines (PNHP 2010). Horned bladderwort is only found in northeastern Pennsylvania on the Allegheny Plateau but is widely distributed in the eastern and southeastern United States and Canada.

<u>Current Threats:</u>

The species is threatened by beaver activity and anthropogenic development that alters hydrologic regime and increases erosion and sedimentation.

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to natural barriers: Horned bladderwort, an aquatic species, is tied to isolated wetlands where it occurs, making movement to a new habitat very difficult if not impossible.

Dispersal and movement: The species does not typically disperse long distances.

Predicted micro sensitivity to changes in temperature: The species is restricted to cool, high elevation wetlands.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Horned bladderwort is dependent on wetland habitat and a moisture regime that is highly vulnerable to loss, reduction, or alteration with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Other interspecific interactions: Horned bladderwort is a carnivorous plant that depends on insects as a 'food' source. A reduction in insects could negatively affect this species ability to obtain nitrogen and survive.

<u>References:</u>

Pennsylvania Natural Heritage Program. 2010. PNHP Fact Sheet – Horned Bladderwort.

Species: Mud Sedge (*Carex limosa*)
Global Rank: G5
State Rank: S2
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Low

Habitat:

Mud sedge is a boreal species found in North America from Labrador and Newfoundland to Alaska and extends south to Delaware, Iowa, Wyoming, and California (Gage and Cooper 2006; NatureServe 2011). In Pennsylvania, mud sedge rarely occurs at higher elevations in open, sphagnum bogs on sphagnum hummocks or as part of the floating mat community (Rhoads and Klein 1993; Gage and Cooper 2006; Rhoads and Block 2007).

Current Threats:

Habitat loss and habitat degradation (e.g., altered hydrological regime) are two major threats to this species.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Mud sedge is found in isolated wetlands in Pennsylvania that are surrounded by extensive forests that would likely serve as barriers against movement to new locations.

Predicted micro sensitivity to changes in temperature: Mud sedge occurs in mostly high elevation sites towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a slightly smaller than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Mud sedge is an obligate wetland plant that has moisture requirements that will likely change as a result of climate change effects.

References:

Gage, E. and D.J. Cooper. 2006. *Carex limosa* L. (mud sedge): a technical conservation assessment . [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/carexlimosa.pdf [Accessed May 2011].

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Ridley, H.N. 1930. The dispersal of plants throughout the world. Reeve and Co., Ashford, Kent, England.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Bog-rosemary (*Andromeda polifolia*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

Habitat:

Bog-rosemary is often found in open peatlands dominated by leatherleaf, sedges, and sphagnum mosses (Rhoads and Klein 1993; Rhoads and Block 2007). Soils are deep, saturated organic and water is nutrient poor and acidic.

Current Threats:

Peatlands, where bog-rosemary occurs, are threatened by beaver activity and subsequent flooding. Formerly, these peatlands in Pennsylvania were subject to peat mining further isolating the wetlands from one another.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural topographic or geographic habitat barriers: Bog-rosemary is limited to high elevation wetlands in the northern tier of Pennsylvania (Allegheny Plateau) where it represents the southern edge of its range.

Dispersal ability: Bog-rosemary produces seeds that may be either wind or water dispersed but dispersal distance is limited thus somewhat increasing its vulnerability. Peatlands, where this species occurs, are often isolated from each other making colonization to a new area difficult.

Predicted micro sensitivity to changes in temperature: This species is found in cool, high elevation wetlands that may be reduced or altered as a result of climate change.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: This species is moderately dependent on a wetland habitat and moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Interspecific interactions: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of bog-rosemary to climate change effects.

Additional Information:

The northern tier of Pennsylvania represents the southern end of bog-rosemary's range. It is possible that the species may retreat northward.

References:

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Creeping Snowberry (*Gaultheria hispidula*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

Habitat:

Creeping snowberry is very specific to partially shaded peatland margins and wet conifer woods in Pennsylvania (Rhoads and Block 2007). Creeping snowberry occurs in the boreal region of North America from southern Canada and the northern United States to the mountains of West Virginia and Maryland. In Pennsylvania, creeping snowberry appears to be confined to the Allegheny Plateau.

Current Threats:

Creeping snowberry is likely to be sensitive to changes in temperature or hydrology at the sites it inhabits. Therefore, disturbances that reduce tree canopy cover or alter the natural hydrological regime may negatively impact the species (PNHP 2007).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Creeping snowberry is limited to isolated, high elevation wetlands in the northern tier of Pennsylvania (Allegheny Plateau) where it represents the southern edge of its range.

Predicted micro sensitivity to changes in temperature: Creeping snowberry occurs in microsites/microhabitats towards the cooler end of the spectrum. In Pennsylvania, creeping snowberry is confined to the cooler northern tier portion of the state.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Creeping snowberry is moderately dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Interspecific interactions: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of creeping snowberry to climate change effects.

References:

Hays, M. 2001. Conservation assessment for creeping snowberry (*Gaultheria hispidula*). USDA Forest Service, Eastern Region.

Pennsylvania Natural Heritage Program. 2007. PNHP Fact Sheet – Creeping Snowberry.

Rhoads, A. and T. Block. 2007. The Plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Species: Labrador-tea (*Rhododendron groenlandicum*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

Habitat:

Labrador-tea grows in unflooded bogs and peaty wetlands (Rhoads and Block 2007). Labrador-tea is widely distributed in the more northern and cooler portions of North America. It occurs locally in northern, mostly northeastern, Pennsylvania (PNHP 2010).

Current Threats:

The species may be threatened by loss of habitat and hydrological alteration of wetlands.

Main Factors Contributing to Vulnerability Rank:

Dispersal and movements: Although Labrador-tea is wind dispersed, dispersal is probably limited to shorter distances (Densmore 1997).

Predicted micro sensitivity to changes in temperature: Labrador-tea occurs in the coolest of local microsites/microhabitats. Labrador-tea is found in the northern tier portion of Pennsylvania, mostly northeastern Pennsylvania.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Labrador-tea is dependent on high elevation wetland habitat that is likely to be highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Interspecific interactions: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of Labrador-tea to climate change effects.

Additional Information:

Pennsylvania represents the southern edge of range for Labrador-tea. Depending on species ability to disperse to suitable habitat, the species may migrate northward in response to changes in temperature and precipitation due to climate change.

References:

Densmore, R.V. 1997. Effects of day length on germination of seeds collected in Alaska. American Journal of Botany 84(2): 274B278.

Gucker, C.L. 2006. *Ledum groenlandicum*. In: Fire effects information system [Online]. USDA, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: http://www.fs.fed.us/database/feis/ [Accessed April 2011].

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Pennsylvania Natural Heritage Program. 2010. PNHP fact Sheet – Labrador-tea.

Rhoads, A. and T. Block. 2007. The Plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Species: Balsam Fir (*Abies balsamea*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Moderate

Habitat:

Balsam fir is widely distributed in North America. The species occurs from Newfoundland west across northern Quebec, northern Ontario, central Manitoba, and Saskatchewan to most of Alberta. In the United States, balsam fir is found in northern Michigan and Wisconsin extending east to the New England states. To the south, scattered populations occur in southern Michigan and Wisconsin, northeast Iowa, Pennsylvania, West Virginia, and northern Virginia (Uchytil 1991; NatureServe 2011). In Pennsylvania, balsam fir is infrequently found in cool bogs and swamps with peat soils in the northern tier of the state (Rhoads and Klein 1993; Rhoads and Block 2007).

Current Threats:

The biggest threats to balsam fir are insect pests and fire (Uchytil 1991). Insect pests such as spruce budworm, hemlock looper, blackheaded budworm, and balsam wooly adelgid can defoliate, stress, and kill trees (Uchytil 1991). Balsam fir is susceptible to severe damage or death from fire due to flammable needles, branches located close to the ground, shallow root systems, and thin, resinous bark.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Balsam fir occurs in isolated high elevation wetlands in northern Pennsylvania where dispersal to suitable habitat may be limited by extensive forests.

Dispersal and movement: Seed dispersal is limited to within 60 m to 160 m of the source (Frank 1990; Uchytil 1991).

Predicted micro sensitivity to changes in temperature: Balsam fir occurs in microsites/microhabitats towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Balsam fir is somewhat dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Forms part of a mutulism: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of balsam fir to climate change effects.

<u>References:</u>

Frank, R.M. 1990. *Abies balsamea* (L.) Mill. Balsam fir. In: Burns, R.M. and B.H. Honkala, technical coordinators. Silvics of North American. Volume 1. Conifers Agricultural Handbook 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 26-35.

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Uchytil, R.J. 1991. *Picea mariana*. In: Fire Effects Formation System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Science Laboratory. Available: http://www.fs.fed.us/database/feid/ [Accessed April 2011].

Species: Red Spruce (*Picea rubens*)
Global Rank: G5
State Rank: S4
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

<u>Habitat:</u>

Red spruce is found at mostly higher elevations in northern Pennsylvania where the climate is cool and soils are derived from glacial till (Rhoads and Klein 1993; Sullivan 1993). Red spruce may be found in moist woodlands or along margins of bogs and swamps (Rhoads and Block 2007). Red spruce occurs from Cape Breton Island, Nova Scotia and New Brunswick west to Maine, southern Quebec, and southeastern Ontario, and south to central New York, northeast Pennsylvania, northern New Jersey, and northeastern Massachusetts. Its range extends south in the Appalachian Mountains of extreme western Maryland, eastern West Virginia, north and western Virginia, western North Carolina, and eastern Tennessee (NatureServe 2011).

<u>Current Threats:</u>

The overall health of red spruce stands seem to be declining due to pollution. Red spruce is negatively impacted by several insect pests (spruce budworm, eastern spruce beetle, European spruce sawfly, and yellow-headed spruce sawfly) (Sullivan 1993).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to natural barriers: Red spruce occurs in mostly isolated high elevation woodlands and bogs and swamps in the northern tier of Pennsylvania that are surrounded by large forest tracts that could serve as a barrier against movement to a new site.

Dispersal and movement: Red spruce seeds are wind and rain disseminated, and limited to only a short dispersal distance within the site (Govindaraju 1988).

Predicted micro sensitivity to changes in temperature: Red spruce occurs in microsites/microhabitats towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species’ range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Red spruce is somewhat dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species’ distribution, abundance, or habitat quality.

Forms part of a mutulism: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of red spruce to climate change effects.

References:

Govindaraju, D.R. 1988. Life histories, neighborhood sizes, and variance structure in some North American conifers. Biological Journal of the Linnean Society 35: 69-78.
Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Sullivan, J. 1993. *Picea rubens*. In: Fire Effects Formation System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Science Laboratory. Available: http://www.fs.fed.us/database/feid/ [Accessed April 2011].

Species: Bog Laurel (*Kalmia polifolia*)
Global Rank: G5
State Rank: S4/S5
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Very High

Habitat:

Bog laurel is found in bogs and peaty wetlands in northeast Pennsylvania (Rhoads and Klein 1993; Rhoads and Block 2007). Bog laurel occurs in the boreal region of North America from Canada to the northern United States where it reaches its southern extent in Pennsylvania.

Current Threats:

Bog laurel is likely to be sensitive to changes in temperature or hydrology at the sites it inhabits.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Bog laurel is limited to isolated, high elevation wetlands in northeast Pennsylvania where it represents the southern edge of its range. These wetlands are often surrounded by extensive forests potentially making movement to new suitable habitat difficult.

Dispersal and movement: Bog laurel seeds are mostly wind and water dispersed (Campbell et al. 2003) and mostly limited to short distance dispersal within the site where established.

Predicted micro sensitivity to changes in temperature: Bog laurel occurs in microsites/microhabitats towards the cooler end of the spectrum. In Pennsylvania, bog laurel is confined to the cooler, northeastern portion of the state.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Bog laurel is moderately dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Interspecific interactions: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of bog laurel to climate change effects (Largent et al. 2006).

References:

Campbell, D.R., L. Rochefort, and C. Lavoie. 2003. Determining the immigration potential of plants colonizing disturbed environments: the case of milled peatlands in Quebec. Journal of Applied Ecology 40(1): 78-91.

Largent, D.L., N. Sugihara, and C. Wishner. 2006. Occurrence of mycorrhizae on ericaceous and pyrolaceous plants in northern California. Canadian Journal of Botany 58(21): 2274-2279.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Dewdrop (*Dalibarda repens*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Low

<u>Habitat:</u>

Dewdrop primarily occurs in the Northeast and Midwest, from Nova Scotia and Quebec to Minnesota and extends south through Pennsylvania and New Jersey to West Virginia and barely extends into North Carolina (NatureServe 2011). In Pennsylvania, dewdrop is found occasionally in bogs, peaty barrens, and cool, mossy woods mostly in the northern tier of the state and at higher elevations along the Allegheny Front (Rhoads and Klein 1993; Rhoads and Block 2007).

<u>Current Threats:</u>

Drainage of wetlands presents a low-level threat for this species (Southern Appalachian Species Viability Project 2002; NatureServe 2011).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to natural topographic or geographic habitat barriers: Dewdrop is limited to rich, moist woods and bogs along the Allegheny front and northern tier of Pennsylvania. Movement to new sites may likely be impeded by extensive upland forests surrounding these areas.

Dispersal and movement: Little is known about the seed dispersal mechanisms of this species, however, dispersal is likely limited to only a short distance within a site.

Predicted micro sensitivity changes in temperature: In Pennsylvania, dewdrop occurs mostly in the cooler portions of the state. The species is found in the northern tier and at higher elevations along the Allegheny Front (Rhoads and Block 2007).

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the mean annual precipitation across the current range of dewdrop in Pennsylvania, the species has experienced slightly lower than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: As a facultative wetland species, dewdrop is somewhat dependent on a moisture regime that is most likely vulnerable to alteration as a result of climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Interspecific interactions: Dewdrop may form mycorrhizal associations that could somewhat increase it's vulnerability to climate change. Dewdrop belongs to the Rosaceae Family, a family that commonly forms mycorrhizal symbionts (Hossler 2010).

References:

Hossler, K. 2010. Nutrient cycling and the role of arbuscular mycorrhizae in created and natural wetlands of central Ohio. Ph.D. dissertation, The Ohio State University.

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Southern Appalachian Species Viability Project. 2002. A partnership between the U.S. Forest Service-Region 8, Natural Heritage Programs in the Southeast, regionally and locally rare species in the Southern Appalachian and Alabama region. Database (Access 97) provided to the U.S. Forest Service by NatureServe, Durham, North Carolina.

Species: Cranberry (*Vaccinium macrocarpon*)
Global Rank: G4
State Rank: SNR
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Very High

Habitat:

Cranberry is scattered across Pennsylvania and occurs in bogs, peaty wetlands, and seepy areas (Rhoads and Klein 1993; Rhoads and Block 2007). Cranberry occupies a large range in northeast North America from Newfoundland to southern Ontario and Central Minnesota to northern Illinois, and in the Appalachian Mountains and along the coastal plain south to North Carolina (NatureServe 2011).

Current Threats:

Cranberry occurs in some very sensitive habitats, making it especially vulnerable to land-use conversion and habitat fragmentation, particularly the conversion of wetlands and bogs (NatureServe 2011).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural topographic or geographic habitat barriers: Within the northern tier of Pennsylvania, cranberry is more limited to isolated wetlands surrounded by extensive forests that form potential natural barriers for dispersal of a wetland plant.

Predicted micro sensitivity to changes in temperature: Cranberry often occurs in microsites/microhabitats towards the cooler end of the spectrum, but is not limited to only cooler conditions.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Cranberry is somewhat dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Forms part of a mutulism: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of cranberry to climate change effects (Largent et al. 2006).

<u>References:</u>

Campbell, D.R., L. Rochefort, and C. Lavoie. 2003. Determining the immigration potential of plants colonizing disturbed environments: the case of milled peatlands in Quebec. Journal of Applied Ecology 40(1): 78-91.

Largent, D.L., N. Sugihara, and C. Wishner. 2006. Occurrence of mycorrhizae on ericaceous and pyrolaceous plants in northern California. Canadian Journal of Botany 58(21): 2274-2279.

NatureServe. 2011. NatureServe Central Databases. Arlington, VA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Cranefly Orchid (*Tipularia discolor*)
Global Rank: G4G5
State Rank: S3
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Very High

Habitat:

The range of the cranefly orchid extends south from New York to Florida and Texas and west from the east coast to Illinois, Missouri, and Oklahoma (NatureServe 2010). It occurs at the northern limit of its range in Pennsylvania/New York, but is restricted to calcareous mesic forests in the southern third of Pennsylvania.

Current Threats:

The cranefly orchid is threatened by deforestation, displacement by exotic plant species, changes in soil chemistry, loss of associated soil mycorrhizae, and deer herbivory (Whigham 1990, 2004).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to anthropogenic barriers: Populations of cranefly orchid that occur in southeast Pennsylvania may experience limitations to northward expansion due to the surrounding urbanization of the landscape and extensive agricultural areas beyond known populations.

Dispersal ability: Although seeds are dust-like in size, dispersal is thought to be a very limited distance (Rasmussen and Whigham 1993).

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Dependence on other species to generate habitat: The need for a mycorrhizal symbiont for germination and seedling establishment increases the vulnerability of this species to climate change (Rasmussen and Whigham 1998).

Interspecific interactions: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of cranefly orchid to climate change effects (Rasmussen and Whigham 1998).

References:

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Rasmussen, H.N. and D.F. Whigham. 1993. Seed ecology of dust seeds in situ: a new study technique and its application in terrestrial orchids. American Journal of Botany 80: 1374-1378.

Rasmussen, H.N. and D.F. Whigham. 1998. Importance of woody debris in seed germination of *Tipularia discolor* (Orchidaceae). American Journal of Botany 85: 829-834.

Whigham, D.F. 1990. The effect of experimental defoliation on the growth and reproduction of a woodland orchid, *Tipularia discolor*. Canadian Journal of Botany 68: 1812-1816.

Whigham, D.F. 2004. Ecology of woodland herbs in temperate deciduous forests. Annual Review of Ecology, Evolution, and Systematics 35: 583-561.

Species: Dwarf Mistletoe (*Arceuthobium pusillum*)
Global Rank: G5
State Rank: S2
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Low

Habitat:

The range of the dwarf mistletoe extends from Minnesota and Pennsylvania north into Canada (NatureServe 2010). It occurs at the southern tier of its range in Pennsylvania but is restricted to circumboreal swamps in northeastern Pennsylvania.

Current Threats:

Dwarf mistletoe is threatened by deforestation, alterations to hydrology, and any other factors contributing to the general loss of its host species, black spruce.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural topographic or geographic habitat barriers: Dwarf mistletoe is limited to black spruce (*Picea mariana*) stands that are often surrounded by a matrix of other forest types that may make migration northward difficult.

Predicted sensitivity to changes in physiological thermal niche: The species is restricted to cool environments where black spruce is found.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Dependent on other species to generate habitat: Dwarf mistletoe is an obligative parasite of black spruce.

References:

Kuijt, J. 1955. Dwarf mistletoes. Botanical Review 21: 569-627.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Bog Sedge (*Carex paupercula*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Very High

Habitat:

Bog sedge is a species of glacial bogs and peatlands. Bog sedge grows in sphagnum and hemlock dominated depressions in a mosaic of drier upland forest on the terminal moraine of the Wisconsin glaciation. In eastern North America, its range extends south to Minnesota, Michigan, Pennsylvania, and New Jersey. In Pennsylvania, it is found at scattered sites in the northeastern and northwestern portions of the state (PNHP 2010).

Current Threats:

The high moisture level, low nutrient status, and extreme acidity of the habitat in which bog sedge grows protect it from most types of disturbance (PNHP 2010). Anthropogenic activities such as logging and road construction that alter the hydrological regime may threaten this species. Beaver activity also alters habitat hydrology. There is no evidence of impact by invasive species. However, browsing by deer may be a problem (PNHP 2010).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Bog sedge is limited to high elevation wetlands in the northern tier of Pennsylvania that are often isolated by extensive forests that may form barriers against northward movement.

Predicted micro sensitivity to changes in temperature: Bog sedge is found in cooler microsites/microhabitats in northeast and northwest Pennsylvania.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Bog sedge is dependent on wetland habitat that is highly vulnerable to loss or reduction with climate change and the expected direction of precipitation change is likely to reduce the species' distribution, abundance, or habitat quality.

References:

Gage, E. and D.J. Cooper. 2006. *Carex limosa* L. (mud sedge): a technical conservation assessment. [online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/carexlimosa.pdf [accessed 4/2011].

Gleason, H.A. and A. Cronquist. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. New York Botanical Garden. New York, NY.

Pennsylvania Natural Heritage Program. 2007. PNHP Fact Sheet – Bog Sedge.

Ridley, H.N. 1930. The dispersal of plants throughout the world. Reeve and Co., Ashford, Kent, England.

Species: False Solomon's-seal (*Maianthemum trifolium*)
Global Rank: G5
State Rank: S4
Climate Change Vulnerability Index: Extremely Vulnerable
Confidence: Moderate

Habitat:

False Solomon's-seal is widely distributed throughout Canada from British Columbia and Yukon Territory in the west to Newfoundland and New Brunswick in the east. In the United States, the species is found in Montana, Minnesota, Wisconsin, Michigan, and the New England States and extends as far south as Pennsylvania and New Jersey (NatureServe 2011). In Pennsylvania, false Solomon's-seal is infrequently found in cool bogs and wetlands with peat soils that occur mostly in the northern tier of the state (Rhoads and Block 2007; Rhoads and Klein 1993).

Current Threats:

Drainage and conversion of wetlands are threats to this species.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: False Solomon's-seal occurs in isolated, high elevation wetlands bordered by extensive forests that may form barriers against northward movement.

Predicted micro sensitivity to changes in temperature: False Solomon's-seal occurs in microsites/microhabitats towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a slightly below average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: False Solomon's-seal is a wetland obligate species and is dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Forms part of a mutulism: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of false Solomon's-seal to climate change effects.

References:

Hossler, K. 2010. Nutrient cycling and the role of arbuscular mycorrhizae in created and natural wetlands of central Ohio. Ph.D. dissertation, The Ohio State University.

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Rhodora (*Rhododendron canadense*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Low

Habitat:

Rhodora is often locally abundant in bogs, peaty wetlands, and barrens in northeast Pennsylvania (Rhoads and Block 2007; Rhoads and Klein 1993). The range of rhodora extends from Newfoundland and Quebec west to Ontario and south to northeastern Pennsylvania and northern New Jersey (NatureServe 2011).

Threats:

Rhodora is likely to be sensitive to changes in temperature or hydrology at the sites it inhabits. Rhodora is mostly shade intolerant so tree species establishment and subsequent canopy development likely reduces populations of this shrub species.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Rhodora is limited to the northeastern corner of Pennsylvania where it represents the southern edge of its range.

Dispersal and movement: Rhodora seeds are wind and water dispersed (Campbell et al. 2003) and mostly limited to short distance dispersal within the site where established.

Predicted micro sensitivity to changes in temperature: Rhodora occur in microsites/microhabitats towards the cooler end of the spectrum. In Pennsylvania, rhodora is confined to the cooler, northeastern portion of the state.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Rhodora is somewhat to moderately dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality. Rhodora often occurs in wetlands but can also occur in drier, barren sites with no overstory canopy.

Forms part of a mutulism: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of rhodora to climate change effects (Largent et al. 2006).

References:

Campbell, D.R., L. Rochefort, and C. Lavoie. 2003. Determining the immigration potential of plants colonizing disturbed environments: the case of milled peatlands in Quebec. Journal of Applied Ecology 40(1): 78-91.

Largent, D.L., N. Sugihara, and C. Wishner. 2006. Occurrence of mycorrhizae on ericaceous and pyrolaceous plants in northern California. Canadian Journal of Botany 58(21): 2274-2279.

NatureServe. 2011. NatureServe Central Databases. Arlington, VA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Goldthread (*Coptis trifolia*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Very High

<u>Habitat:</u>

Goldthread occupies a circumboreal range for Greenland across North America to Alaska, including most of Canada and the eastern United States. Goldthread also occurs in northeast Asia to northern Japan. There are also two disjunct populations in the western United States, in Washington and Oregon (Stein 1998; NatureServe 2011). In Pennsylvania, goldthread is common in rich, damp, mossy woods, bogs, and swamps found in the northern tier of the state and at higher elevations along the Allegheny Front (Rhoads and Klein 1993; Rhoads and Block 2007).

<u>Current Threats:</u>

Many activities pose a threat this understory species, such as logging, hydrologic change, soil disturbance, reductions in downed woody debris, and possibly high intensity fires (Stein 1998; NatureServe 2011).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to natural topographic or geographic habitat barriers: Goldthread is limited to rich, moist woods, bogs, and swamps along the Allegheny Front and northern tier of Pennsylvania. The drier forests that surround and isolate goldthread habitat may serve as barriers against movement to new locations.

Dispersal and movement: Little is known about the seed dispersal mechanisms of this species, however, dispersal is likely limited to only a short distance within a site.

Predicted micro sensitivity changes in temperature: In Pennsylvania, goldthread occurs mostly in the cooler portions of the state. The species is found in the northern tier and at higher elevations along the Allegheny Front (Rhoads and Block 2007).

Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: As a facultative wetland species, goldthread is dependent on a moisture regime that is most likely vulnerable to alteration as a result of climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Interspecific interactions: Reliance of a mycorrhizal symbiont (Malloch and Malloch 1981; Hossler 2010) somewhat increases the vulnerability of goldthread to climate change effects.

References:

Hossler, K. 2010. Nutrient cycling and the role of arbuscular mycorrhizae in created and natural wetlands of central Ohio. Ph.D. dissertation, The Ohio State University.
Malloch, D. and B. Malloch. 1981. The mycorrhizal status of boreal plants: species from northeastern Ontario. Canadian Journal of Botany 59: 2167-2172.

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Stein, M. 1998. Conservation assessment for *Coptis trifolia* (L.) Salisb. USDA Forest Service Region 6 and USDI Bureau of Land Managemen, Oregon and Washington.

Species: Small Cranberry (*Vaccinium oxycoccos*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Moderate

Habitat:

Although small cranberry occurs in scattered patches across Pennsylvania, most occurrences are documented in the northeastern portion of the state (Rhoads and Klein 1993). Small cranberry can be found in bogs and peaty wetlands (Rhoads and Block 2007). Small cranberry is widespread in boreal North America (NatureServe 2011).

Current Threats:

Small cranberry occurs in some very sensitive habitats, making it especially vulnerable to land-use conversion and habitat fragmentation, particularly the conversion of wetlands and bogs (NatureServe 2011).

Main Factors Contributing to Vulnerability Rank:

Dispersal and movement: Small cranberry seeds are bird and small mammal dispersed (Campbell et al. 2003) and probably mostly limited to dispersal within the site.

Predicted micro sensitivity to changes in temperature: Small cranberry occurs in microsites/microhabitats towards the cool or cold end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Small cranberry is almost completely dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Forms part of a mutulism: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of small cranberry to climate change effects (Largent et al. 2006).

References:

Campbell, D.R., L. Rochefort, and C. Lavoie. 2003. Determining the immigration potential of plants colonizing disturbed environments: the case of milled peatlands in Quebec. Journal of Applied Ecology 40(1): 78-91.

Largent, D.L., N. Sugihara, and C. Wishner. 2006. Occurrence of mycorrhizae on ericaceous and pyrolaceous plants in northern California. Canadian Journal of Botany 58(21): 2274-2279.

NatureServe. 2011. NatureServe Central Databases. Arlington, VA.

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Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Black Spruce (*Picea mariana*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Low

<u>Habitat:</u>

Black spruce is distributed transcontinentally across northern North America from Newfoundland and northern Quebec west across northern Canada to the west coast of Alaska, south to British Columbia, south and east to central Minnesota, and east to Rhode Island and Massachusetts. Black spruce occurs in isolated patches along the southern portion of its range in southern Wisconsin, southern Michigan, Pennsylvania, and New Jersey (Uchytil 1991; NatureServe 2011). In Pennsylvania, black spruce is rarely found in high elevation bogs in the northeast portion of the state (Rhoads and Klein 1993; Rhoads and Block 2007).

<u>Current Threats:</u>

Black spruce is susceptible to damage from flooding and disruptions in normal groundwater movements. Black spruce does not compete well with other woody tree species. Infection by eastern dwarf mistletoe (*Arceuthobium pusillum*) greatly damages black spruce stands (Uchytil 1991).

<u>Main Factors Contributing to Vulnerability Rank:</u>

Distribution relative to natural barriers: Black spruce occurs in mostly high elevation bogs in northeast Pennsylvania that are often separated by extensive upland forests that will likely serve as barriers against movement to new locations.

Dispersal and movement: Seed dispersal is mostly limited to within 80 m of the source (Uchytil 1991).

Predicted micro sensitivity to changes in temperature: Black spruce occurs in microsites/microhabitats towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, black spruce has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Black spruce is somewhat dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Forms part of a mutulism: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of black spruce to climate change effects.

References:

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Uchytil, R.J. 1991. *Picea mariana*. In: Fire Effects Formation System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Science Laboratory. Available: http://www.fs.fed.us/database/feid/ [Accessed April 2011].

Species: Great Spurred Violet (*Viola selkirkii*)
Global Rank: G5?
State Rank: S3
Climate Change Vulnerability Index: Highly Vulnerable
Confidence: Very High

Habitat:

Great spurred violet occupies the boreal regions of North America south to Pennsylvania, Minnesota, and British Columbia, with disjunct occurrences in the Black Hills of South Dakota and the Rocky Mountains of Colorado and New Mexico (Gleason and Cronquist; NatureServe 2010). The species occurs in circumboreal forests underlain by basic soils or limestone in Pennsylvania.

Current Threats:

Great spurred violet is threatened by deforestation and displacement by exotic plant species.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural topographic or geographic habitat barriers: Great spurred violet is mostly limited to moist, cool ravines and is unlikely to migrate upslope where microsite conditions are different.

Dispersal and movement: Seeds are both ant and ballistically dispersed with a mean dispersal distance of less than a meter (Ohkawara and Higashi 1994).

Predicted micro sensitivity to changes in temperature: The species occupies moist, shaded ravines, and cold boreal and hardwood forest habitats throughout its range (Hornbeck et al. 2003). The species is limited to the cool environment found in the northern tier of Pennsylvania.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a slightly lower than average precipitation variation in the past 50 years.

References:

Gleason, H.A. and A. Cronquist. 1991. Manual of the vascular plants of northeastern United States and adjacent Canada, Second Edition. New York, New York: New York Botanical Garden. 910p.

Hornbeck, J.H., C.H. Sieg, and D.J. Reyher. 2003. Conservation assessment for great-spurred violet in the Black Hill National Forest, South Dakota and Wyoming. US

Department of Agriculture, Forest Service, Rocky Mountain Region, Black Hills National Forest, Custer, South Dakota.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Ohkawara, K. and S. Higashi. 1994. Relative importance of ballistic and ant dispersal in two diplochorous *Viola* species (Violaceae). Oecologia 100:135-140.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Wild Limestone Petunia (*Ruellia strepens*)
Global Rank: G4G5
State Rank: S2
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Very High

Habitat:

The range of the wild limestone petunia extends south from Pennsylvania, Michigan, and Nebraska to Florida and Texas (NatureServe 2010). Wild limestone petunia occurs at the northern edge of its range in Pennsylvania and is restricted to mesic forests, bluffs, and roadsides on calcareous soils in the southern third of Pennsylvania (Rhoads and Block 2007).

Current Threats:

Wild limestone petunia is threatened by deforestation, displacement by exotic plant species, and deer herbivory.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural topographic or geographic habitat barriers: Wild limestone petunia is mostly limited to low slope mesic conditions and is unlikely to migrate upslope where microsite conditions are different.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Restrictions to uncommon geological features: The species is restricted to mesic calcareous forests in Pennsylvania. Such habitat is fairly uncommon in Pennsylvania.

References:

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The Plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Species: Water Bulrush (*Schoenoplectus subterminalis*)
Global Rank: G4G5
State Rank: S3
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Low

Habitat:

Water bulrush has disjunct eastern and western North American ranges. The species is absent from the Great Plains, but is found in the west from southern Alaska to California, Idaho, Utah, and Montana. In the east, water bulrush occurs from Newfoundland to Ontario, south to South Carolina, Georgia, and Missouri (Williams 1990; NatureServe 2011). In Pennsylvania, water bulrush is found in quiet waters of lakes, ponds, vernal pools, and slow-moving boggy streams in the northeast, northwest, and south central portions of the state (Rhoads and Klein 1993; Rhoads and Block 2007).

Current Threats:

The species may experience some low-level threats from drainage of wetlands such as beaver ponds and bogs (Southern Appalachian Species Viability Project 2002; NatureServe 2011). Sudden changes in water levels and mechanical disturbance of submerged vegetation may also threaten this species (Cusick 1984).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Water bulrush occurs in isolated ponds, vernal pools, lakes, and slow-moving streams where movement to another body of water for establishment may be very limited or improbable.

Dispersal and movement: Like many *Schoenoplectus* species, water bulrush dispersal is probably mostly limited to the site where it occurs. Seeds drop from the parent plants and form seed banks in the sediment. The potential for dispersal to new sites could occur if water bulrush is found in a stream and seeds are dispersed downstream.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Water bulrush is a wetland obligate species but is usually found in deeper portions of shallow bodies of water that may or may not be dramatically affected by moisture loss due to climate change.

Forms part of a mutulism: Like other *Schoenoplectus* species, water bulrush probably shares a similar reliance on mycorrhizal associations (Hossler 2010).

References:

Cusick, A.W. 1984. *Schoenoplectus subterminalis* (Torr.) Sojak. Ohio Department of Natural Resources, Division of Natural Areas and Preserves.

Hossler, K. 2010. Nutrient cycling and the role of arbuscular mycorrhizae in created and natural wetlands of central Ohio. Ph.D. dissertation, The Ohio State University.

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Southern Appalachian Species Viability Project. 2002. A partnership between the U.S> Forest Service-Region 8, Natural Heritage Programs in the Southeast, regionally and locally rare species in the Southern Appalachian and Alabama region. Database (Access 97) provided to the U.S. Forest Service by NatureServe, Durham, North Carolina.

Williams, T.Y. 1990. *Schoenoplectus subterminalis*. In: Fire Effects Information System [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: http://www.fs.fed.us/database/feis/ [Accessed: May 2011].

Species: Willow Oak (*Quercus phellos*)
Global Rank: G5
State Rank: S2
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Very High

Habitat:

Willow oak occurs from Illinois and New York to Texas and Florida (NatureServe 2010). The natural habitat for willow oak consists primarily of bottomland forests along the Coastal Plain physiographic province in Pennsylvania but the species is occasionally planted as an ornamental tree throughout the state.

Current Threats:

Willow oak is threatened by deer herbivory and displacement by exotic plant species.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to anthropogenic factors: The migration of willow oak in Pennsylvania is mostly restricted by heavy urbanization along the Coastal Plain. However, the fact that the species is planted as an ornamental may allow for movement beyond Philadelphia and the surrounding suburbs.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: This species is moderately dependent on a moisture regime that is highly vulnerable to alteration due to climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Restriction to uncommon geological features or derivatives: The species is restricted to mostly to wet, sandy coastal soils in Pennsylvania.

References:

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Screwstem (*Bartonia paniculata*)
Global Rank: G5T5
State Rank: S3
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Moderate

Habitat:

Screwstem is an obligate wetland species that occurs from New England and Ontario, Canada to Texas and Florida (NatureServe 2010). In Pennsylvania, this species is found in bogs, swamps, and wet meadows.

Currents Threats:

Screwstem is threatened by habitat loss, alterations to wetland hydrology, displacement by exotic plant species, and succession that results in shading (twining screwstem is shade intolerant).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural topographic or geographic habitat barriers: Screwstem is limited to bogs, swamps, and wet meadows that tend to be separated by upland habitat that would make migration for a wetland obligate species very difficult.

Dispersal and movements: It is likely that dispersal is limited to short distances within a site (Hill 2003). Given that the wetland habitat where this species is found is generally isolated, it is unlikely that seeds can disperse long distances to new, suitable habitat.

Predicted micro sensitivity to changes in temperature: Considering the range of the species in Pennsylvania, some populations are restricted to relatively cool wetlands that may be lost or reduced due to climate change.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Screwstem is an obligate wetland species and is dependent on a moisture regime that may be vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to affect the species' distribution, abundance, or habitat quality. Hill (2003) suggests that the need for continuous moisture appears to be crucial for this species.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a small precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Climate models suggest a likely increase in precipitation amount and patterns for Pennsylvania that will likely have a negative impact on the species' habitat quality.

Interspecific interactions: Screwstem utilizes one or several mycorrhizal associates (Hill 2003).

References:

Hill, S.R. 2003. Conservation assessment for twining screwstem (*Bartonia paniculata*) (Michx.) Muhl. USDA Forest Service. Milwaukee, Wisconsin. USA.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Thread Rush (*Juncus filiformis*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Very High

Habitat:

Thread rush occupies a variety of moist or wet habitats including sandy shores of streams and lakes, bogs, and alpine meadows (Gleason 1952; Hays 2001). It prefers sandy soils but the species is also found in sphagnum bogs and shrub swamps with peaty soils (Hays 2001). In North America, thread rush has a mostly northern distribution from Alaska to Greenland and southward in New England and the Great Lakes and Rocky Mountain states (Gleason 1952; Hayes 2001). In Pennsylvania, rare populations are found in the northeastern and northwestern portions of the Allegheny Plateau (Rhodes and Block 2007).

Current Threats:

Loss of wetlands threatens this species (NatureServe 2010).

Main factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Thread rush is limited to wetlands in mostly the northeastern portion of Pennsylvania (with only two additional populations known in northwestern Pennsylvania) where it represents the southern edge of its range. Movement between wetlands may be difficult given that they are often separated by upland habitat.

Predicted micro sensitivity to changes in temperature: This species is found in high elevation wetlands that tend to be cooler.

Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: This species is moderately dependent on a wetland habitat and moisture regime that is vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species’ distribution, abundance, or habitat quality.

Additional Information:

Since Pennsylvania represents the southern edge-of-range for thread rush, depending on the species response to temperature and precipitation variation, we may see a northward migration of the species out of the state.

References:

Gleason, H.A. 1952. Illustrated flora of the northeastern United States and adjacent Canada, vol 2. Published for the New York Botanical Garden by Hafner Press, New York, N.Y. 665p.

Hayes, M. 2001. Conservation Assessment for thread rush (*Juncus filiformis*) for USDA Forest Service, Eastern Region.

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Richards, P.W. 1943. *Juncus filiformis* L. Journal of Ecology 31:1.

Wisheu, I.C. and P.A. Keddy. 1991. Seed banks of a rare wetland plant community: distribution patterns and effects of human induced disturbance. Journal of Vegetation Science 2: 181-188.

Species: White Trout-lily (*Erythronium albidum*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Very High

Habitat:

White trout lily occurs from Minnesota and Canada south to Texas and Georgia (NatureServe 2010). In Pennsylvania, this species occurs in mesic and floodplain forests on calcareous soils (Rhoads and Block 2007).

Current Threats:

White trout lily is threatened by deer herbivory and displacement from exotic plant species especially garlic mustard (*Alliaria petiolata*).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural topographic or geographic habitat barriers: White trout-lily is mostly limited to floodplains and low, mesic slopes and will unlikely migrate upslope where microsite conditions are drier.

Dispersal and movements: Mechanisms for seed dispersal are mostly ant-dispersed and gravity and limited to a short dispersal distance.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of the mean annual precipitation across the species' range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Restriction to uncommon geological features: The species is restricted to mesic, calcareous forests in Pennsylvania. Such habitat is fairly uncommon in Pennsylvania

Dependence on other species for propagule dispersal: While vegetative reproduction can be high in white trout lily (Muller 1979, Morly 1992), seeds are adapted for ant dispersal (Thompson 1981).

References:

Morley, T. 1982. Flowering frequency and vegetative reproduction in *Erythronium albidum* and *E. propullens*, and related observations. Bulletin of the Torrey Botanical Club 109: 169-176.

Muller, R.N. 1979. Biomass accumulation and reproduction in *Erythronium albidum*. Bulletin of the Torrey Botanical Club 106:276-283.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The Plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Thompson, J.N. 1981. Elaiosomes and fleshy fruits: phenology and selection pressures for ant-dispersed seeds. American Naturalist 117: 104-108.

Species: Leatherleaf (*Chamaedaphne calyculata*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Very High

Habitat:

Leatherleaf occurs frequently in bogs and acidic wetlands in the northern tier of Pennsylvania and at high elevations along the Allegheny Front (Rhoads and Block 2007; Rhoads and Klein 1993). Leatherleaf is circumboreal and is found throughout Alaska and Canada. Its distribution extends southward through the Great Lake states and into the northeastern United States.

Current Threats:

Leatherleaf is likely to be sensitive to changes in temperature or hydrology at the sites it inhabits. Leatherleaf is shade intolerant so the development of a tall shrub layer or establishment of trees reduces leatherleaf cover at a site.

Main Factors Contributing to Vulnerability Rank:

Predicted micro sensitivity to changes in temperature: Leatherleaf occurs in microsites/microhabitats towards the cooler end of the spectrum.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Leatherleaf is moderately dependent on a moisture regime that is highly vulnerable to loss or reduction with climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Forms part of a mutulism: Reliance on a mycorrhizal symbiont somewhat increases the vulnerability of leatherleaf to climate change effects (Selosse et al. 2007).

References:

Pavek, D.S. 1993. *Chamaedaphne calyculata*. In: Fire Effects Information System, [Online]. Rocky Mountain Research Station, Fire Sciences Laboratory. Available: http://www.fs.fed.us/database/feis/ [Accessed April 2011].

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Selosse, M.A., S. Setaro, F. Glatard, F. Richard, C. Urcelay, and M. Weiss. 2007. Sebacinales are common mycorrhizal associates of Ericaceae. New Phytologist 174: 864-878.

Species: Bunchberry (*Cornus canadensis*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Moderate

Habitat:

The global range of bunchberry extends from Greenland across North America to northeast Asia. In the United States, bunchberry occupies the northern tier states and extends south into West Virginia and Virginia in the northeast (NatureServe 2011). In Pennsylvania, bunchberry is found occasionally in cool, damp woods, bogs, and swamp edges mostly in the northern tier of the state and at higher elevations along the Allegheny Front (Rhoads and Klein 1993; Rhoads and Block 2007).

Current Threats:

Land-use conversion, habitat fragmentation, and forest management practices are low level threats to this species (Southern Appalachian Species Viability Project 2002; NatureServe 2011).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural topographic or geographic habitat barriers: Bunchberry is mostly limited to bogs and swamps in the northern tier of Pennsylvania and at higher elevations along the Allegheny Front. These semi-aquatic/aquatic habitats are often isolated from one another by extensive upland forests that could make movement to a new site difficult.

Predicted micro sensitivity changes in temperature: In Pennsylvania, bunchberry occurs mostly in the cooler portions of the state. The species is found in the northern tier and at higher elevations along the Allegheny Front (Rhoads and Block 2007).

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the range of mean annual precipitation across the current range of bunchberry in Pennsylvania, the species has experienced slightly lower than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Bunchberry is somewhat dependent on a moisture regime that is most likely vulnerable to alteration as a result of climate change and the expected direction of moisture change is likely to reduce the species' distribution, abundance, or habitat quality.

Interspecific interactions: Bunchberry forms mycorrhizal associations that could somewhat increase it's vulnerability to climate change (Summerbell 1989).

<u>References:</u>

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Southern Appalachian Species Viability Project. 2002. A partnership between the U.S> Forest Service-Region 8, Natural Heritage Programs in the Southeast, regionally and locally rare species in the Southern Appalachian and Alabama region. Database (Access 97) provided to the U.S. Forest Service by NatureServe, Durham, North Carolina.

Summerbell, R.C. 1989. Microfungi associated with the mycorrhizal mantle and adjacent microhabitats within the rhizosphere of black spruce. Canadian Journal of Botany 64: 1085-1095.

Species: White Beak-rush (*Rhynchospora alba*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Moderately Vulnerable
Confidence: Low

Habitat:

White beak-rush occurs from Alaska and Canada, ranging southward in the United States to Georgia and Alabama in the east and to California in the west (NatureServe 2011). The species extends as far as Puerto Rico (in the upper Luquillo Mountains), and also in Eurasia. In Pennsylvania, white beak-rush is found occasionally in bogs and swamps and is sparsely scattered throughout the state (Rhoads and Klein 1993; Rhoads and Block 2007).

Current Threats:

White beak-rush is highly threatened by land use conversion, habitat fragmentation, and pollution. The species is also threatened, to a lesser extent, by succession and forest management practices (Southern Appalachian Species Viability Project 2002; NatureServe 2011).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: White beak-rush is found in isolated wetlands in Pennsylvania that are surrounded by extensive upland forests that may likely serve as barriers against movement to new locations.

Dispersal and movement: Little is known about the dispersal of white beak-rush but the presence of bristled achenes may mean that dispersal can be facilitated by animals. However, dispersal is probably limited to a short distance within a site.

Predicted micro sensitivity to changes in temperature: White beak-rush is found mostly in cooler wetlands at higher elevations.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Within the species range in Pennsylvania, the species has experienced a slightly less than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Whit beak-rush is an obligate wetland species that has moisture requirements that will likely change as a result of climate change.

References:

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Southern Appalachian Species Viability Project. 2002. A partnership between the U.S> Forest Service-Region 8, Natural Heritage Programs in the Southeast, regionally and locally rare species in the Southern Appalachian and Alabama region. Database (Access 97) provided to the U.S. Forest Service by NatureServe, Durham, North Carolina.

Species: Bog Goldenrod (*Solidago uliginosa*)
Global Rank: G4G5
State Rank: S3
Climate Change Vulnerability Index: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

Bog goldenrod is found in bogs, fens, sedge meadows and open wooded peatlands (Rhoads and Block 2007). The species is found in many of the states in the eastern United States and Canada. It occurs throughout Pennsylvania.

Current Threats:

The species is threatened by beaver activity and anthropogenic development that alters hydrologic regime and increases sedimentation.

Main Factors Contributing to Vulnerability Rank:

Although bog goldenrod may be impacted by hydrological alterations due to climate change, the CCVI suggests that the species is Not VulnerablePresumed Stable. Available evidence does not suggest that the abundance and/or range extent within Pennsylvania will change (increase/decrease) substantially by 2050. However, actual boundaries may change. Longer distance seed dispersal and habitat versatility are characteristics that may make this species more resilient to climate change as indicated by the CCVI. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

Rhoads, A. and T. Block. 2007. The Plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Species: Mistflower (*Conoclinum coelestinum*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

The range of mistflower extends from Illinois and Pennsylvania south to Florida and Texas (NatureServe 2010). The species is considered exotic in New York, Wisconsin, and Canada. Mistflower occurs along floodplains as well as pond and stream margins. The species also occurs in fields, wet meadows, and along road shoulders (Rhoads and Block 2007), which suggests it is not specifically tied to a particular hydrological regime.

Current Threats:

Mistflower is threatened by deer herbivory and displacement due to exotic plant species.

Main Factors Contributing to Vulnerability Rank:

The CCVI rank for mistflower suggests that the species is Not Vulnerable/Presumed Stable. Available evidence does not suggest that the abundance and/or range extent within Pennsylvania will change (increase/decrease) substantially by 2050. However, actual range boundaries may change. Longer distance seed dispersal, habitat versatility, and lesser hydrological dependence are characteristics that may make this species more resilient to climate change as indicated by the CCVI. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Purple Bedstraw (*Galium latifolium*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

Purple bedstraw occurs within the Appalachian Mountains from Pennsylvania to Georgia/Alabama (NatureServe 2010). In Pennsylvania, the species occurs at the northern tier of its range on dry to mesic forests underlain by sandstone and shale.

Current Threats:

Purple bedstraw is threatened by deer herbivory and displacement due to exotic plant species.

Main Factors Contributing to Vulnerability Rank:

Results from the CCVI analysis suggest that purple bedstraw is Not Vulnerable/Presumed Stable. Available evidence does not suggest that the abundance and/or range extent within Pennsylvania will change (increase/decrease) substantially by 2050. However, actual boundaries may change. Several characteristics, such as tolerance to a wide range of climatic conditions and longer distance dispersal potential, contribute to the short-term climate change resilience indicated by the CCVI. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

Gucker, C.L. 2005. *Galium boreale, G. triflorum*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Ricky Mountain Research Station, Fire Sciences Laboratory. Available: http://www.fs.fed.us/database/feis/ [Accessed: April 2011].

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Toothcup (*Rotala ramosior*)
Global Rank: G5
State Rank: S3
Climate Change Vulnerability Index: Not Vulnerable/Presumed Stable
Confidence: Moderate

Habitat:

Toothcup occurs throughout most of the United States and in southern Canada (NatureServe 2010). Toothcup is typically found in early successional wet habitats such as mudflats and lake, pond, and reservoir shores and almost always on newly exposed shores following water drawdowns (Mattrick 2001).

Current Threats:

Toothcup is threatened by alterations to hydrologic regime and displacement by exotic plant species.

Main Factors Contributing to Vulnerability Rank:

Although toothcup may be sensitive to certain climate change related factors addressed in the CCVI, such as changes in moisture regimes, results from the CCVI suggest that the species is Not Vulnerable/Presumed Stable. Available evidence does not suggest that abundance and/or range extent within Pennsylvania will change substantially by 2050 although actual range boundaries may change. Multiple vehicles for dispersal (e.g., wind, gravity, water, and the feet of waterfowl) and a preference towards warmer environments are characteristics that contribute to the short-term climate change resilience indicated by the CCVI. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

Mattrick, C. 2001. *Rotala ramosior* (L.) Koehne (Toothcup) Conservation and Research Plan. New England Wild Flower Society, Framingham, Massachusetts. USA.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Species: Meadow Willow (*Salix petiolaris*)
Global Rank: G5
State Rank: S4
Climate Change Vulnerability Index: Not Vulnerable\Presumed Stable
Confidence: Very High

Habitat:

The range of meadow willow extends from Colorado and New Jersey to northern Canada (NatureServe 2010). The species occurs in wet meadows, fens, along stream banks and lakeshores, and in forest clearings (Rhoads and Block 2007). The species requires direct sunlight and will grow in a variety of moist soil conditions. It is associated with disturbed and early successional habitat.

Current Threats:

Meadow willow is threatened by deer herbivory and displacement by exotic plant species.

Main Factors Contributing to Vulnerability Rank:

Although meadow willow is at its southern range limit in Pennsylvania and requires a localized hydrological regime that may experience some drying due to climate change, its CCVI rank suggests that the species is Not Vulnerable/Presumed Stable. Available evidence does not suggest that the abundance and/or range extent within Pennsylvania will change (increase/decrease) substantially by 2050. However, actual range boundaries may change. Longer distance dispersal and the ability to grow in moist conditions in a variety of soil conditions are characteristics that contribute to the short-term climate change resilience indicated by the CCVI. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

Gage, E.A. and D.J. Cooper. 2005. Patterns of willow seed dispersal, seed entrapment, and seedling establishment in a heavily browsed montane riparian ecosystem. Canadian Journal of Botany 83:678-687.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Species: Tawny Cotton-grass (*Eriophorum virginicum*)
Global Rank: G5
State Rank: SNR
Climate Change Vulnerability Index: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

Tawny cotton-grass occurs in most of the eastern half of Canada and extends from Minnesota to the east coast of the United States and south to Florida (NatureServe 2011). The species is widely dispersed in Pennsylvania (Rhoads and Klein 1993), and is found in bogs, peaty meadows, and peaty swamps where soils remain saturated throughout the growing season (Cusick 1981; Rhoads and Block 2007).

Current Threats:

Drainage and conversion of wetlands and bog succession are threats to the species (Southern Appalachian Species Viability Project 2002; NatureServe 2011).

Main Factors Contributing to Vulnerability Rank:

Results from the CCVI analysis suggest that tawny cotton-grass is Not Vulnerable/Presumed Stable. Available evidence does not suggest that the abundance and/or range extent within Pennsylvania will change (increase/decrease) substantially by 2050. However, actual boundaries may change. The ability to disperse longer distances, lack of barriers to movement, and a widespread range throughout Pennsylvania are all factors that contribute to the short-term climate change resilience indicated by the CCVI. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

Cusick, A.W. 1982. *Eriophorum virginicum* abstract. Division of Natural Areas and Preserves, Ohio Department of Natural Resources. www.dnr.state.oh.us/Portals/3/Abstracts/.../Eriophorum_virginicum.pdf [Accessed April 2011].

NatureServe. 2011. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Rhoads, A. and W.M. Klein. 1993. The vascular flora of Pennsylvania annotated checklist and atlas. American Philosophical Society, Philadelphia, PA.

Southern Appalachian Species Viability Project. 2002. A partnership between the U.S. Forest Service-Region 8, Natural Heritage Programs in the Southeast, regionally and locally rare species in the Southern Appalachian and Alabama region. Database (Access 97) provided to the U.S. Forest Service by NatureServe, Durham, North Carolina.

Species: Eastern Sand Cherry (*Prunus pumila* var. *depressa*)
Global Rank: G5T5
State Rank: S1
Climate Change Vulnerability Index: Not Vulnerable/Presumed Stable
Confidence: Moderate

Habitat:

Eastern sand cherry extends from Kentucky and Pennsylvania to Canada (Taylor 2006; NatureServe 2010). In Pennsylvania, this species occurs in cobble/sand riverine prairies along the Delaware and Susquehanna Rivers (Rhoads and Block 2007).

Current Threats:

Eastern sand cherry is threatened by alterations to hydrologic regime and displacement by exotic plant species.

Main Factors Contributing to Vulnerability Rank:

Eastern sand cherry may be sensitive to certain climate change related factors addressed in the CCVI, such as physical habitat restrictions (restricted to gravel/cobble substrate found on island heads and along shorelines) and reduction in ice scour action that helps to maintain the sparse, gravel/cobble substrate colonized by eastern sand cherry (however, flooding can have a similar effect). However, results from the CCVI suggest that the species is Not Vulnerable/Presumed Stable. Available evidence does not suggest that abundance and/or range extent within Pennsylvania will change substantially by 2050 although actual range boundaries may change. The potential for longer distance dispersal via water, birds, or mammals, no strong ties to specific thermal or hydrological niches (as defined by the CCVI), and a habitat preference that benefits from flooding are characteristics that contribute to the short-term climate change resilience indicated by the CCVI. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.

Rhoads, A. and T. Block. 2007. The Plants of Pennsylvania. 2nd Edition. Philadelphia. University of Pennsylvania Press.

Taylor, J. 2006. *Prunus pumila*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: http://www.fs.fed.us/database/feis/ [Accessed: April 2011].

REPTILES

Species: Bog Turtle (*Glyptemys muhlenbergii*)
Global Rank: G3
State Rank: S2
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species, also PA Endangered and Federally Threatened
Climate Change Vulnerability: Highly Vulnerable
Confidence: High

Habitat:

Bog turtles inhabit calcareous fens, sphagnum bogs, and wet, grassy pastures that are characterized by soft, muddy substrates and perennial groundwater seepage (NJDEP 2010). Bog turtle habitats are usually well-drained with very shallow surface waters (PNHP 2007). The species requires open areas for basking and nesting surrounded by early successional wetland vegetation. The range of the bog turtle is discontinuous and confined to the eastern United States. The main range is from western Massachusetts, Connecticut, and eastern New York southward through eastern Pennsylvania and New Jersey to northern Delaware and northern Maryland (Ernst et al. 1994). The bog turtle occurs in very low numbers in southeastern Pennsylvania (PNHP 2007).

Current Threats:

Spotty distribution and specialized habitat requirements make this species vulnerable to local extirpation. Decline is primarily due to loss, degradation, and fragmentation of habitat and excessive (and illegal) collecting for the pet trade (Ernst et al. 1994). Bog turtle populations may suffer from low new recruitment due to predation by raccoon and trampling by humans walking through the habitat. The species is vulnerable to the usual problems associated with small population sizes.

Main Factors Contributing to Vulnerability Rank:

Distribution relative to natural barriers: Natural barriers between suitable habitat, such as large forest tracts and mountains, could greatly limit this species ability to move northward in response to climate change.

Distribution relative to anthropogenic barriers: Much of the current and potential habitat to the north is already heavily impacted by man thus limiting dispersal opportunities.

Dispersal and movements: Bog turtles tend to remain within suitable habitat patches, and rarely move more than 100 m in a year, making potential movement to a new habitat patch unlikely (NatureServe 2010).

Physical habitat specificity: The species is moderately to highly specialized in its habitat requirements.

Dependence on other species to generate habitat: Bog turtle habitat is created and maintained largely by two species, beaver and man. Livestock grazing also helps to maintain vegetation succession and softens the ground, thus creating favorable conditions for bog turtles (NJDEP 2010).

References:

Ernst, C.H., J.E. Lovich, and R.W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington and London.

Hulse, A.C., C.J. McCoy, and E. Censky. 2001. Amphibians and reptiles of Pennsylvania and the Northeast. Comstock Publishing Associates. Cornell University Press, Ithaca. 419 pp.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia, USA.

New Jersey Department of Environmental Protection – Division of Fish and Wildlife. (accessed 3/2010). Fact Sheet – Bog turtle http://www.njfishandwildlife.com/ensp/pdf/end-thrtened/bogtrtl.pdf.

Pennsylvania Natural Heritage Program. 2007. Fact Sheet – Bog Turtle.

Species: Spotted Turtle (*Clemmys guttata*)
Global Rank: G5
State Rank: S3
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Moderately Vulnerable
Confidence: Moderate

Habitat:

Spotted turtles use a wide variety of wetland habitats with soft bottoms and aquatic vegetation (Ernst et al. 1994; Hulse et al. 2001; NatureServe 2010). Spotted turtles use mostly unpolluted, small, shallow bodies of water such as small marshes, marshy pastures, bogs, fens, woodland streams, swamps, small ponds, and vernal pools. They may also use brackish tidal streams. Ponds surrounded by relatively undisturbed meadow or undergrowth are most favorable. Spotted turtles often bask along the water's edge, on brush piles in water, and on logs or vegetation clumps. When inactive, they hide in bottom mud and detritus or in muskrat burrows. The species range extends from southern Maine, southern Ontario, lower peninsula of Michigan, and northeastern Illinois, south to central Indiana, central Ohio, and Pennsylvania, and southward along the U.S. east coast from New England to northern or northcentral Florida (Ernst et al. 1994; NatureServe 2010). In Pennsylvania, spotted turtles occur both in the southeastern Coastal Plain and Piedmont and in the west. They are absent from most of the Ridge and Valley Providence and north-central and northeastern portions of the state (Hulse et al. 2001).

Current Threats:

Primary threats to this species are habitat fragmentation and alteration, livestock grazing, draining and filling of wetlands, road mortality, collecting, artificial manipulation of water levels, and pollution (NatureServe 2010).

Main Factors Contributing to Vulnerability Rank:

Distribution relative to anthropogenic barriers: Portions of the current distribution of spotted turtles in Pennsylvania is bordered by significant urbanization which would make movement in response to climate change very difficult.

Dispersal and movements: The species is characterized by limited to moderate dispersal capability to new sites. Ernst et al. (1994) reported several studies with spotted turtle movement ranging from 20 m to under 500 m within their home range. Movement beyond a home range may be limited by habitat availability.

Predicted macro sensitivity to changes in precipitation, hydrology, or moisture regime: Considering the species range within Pennsylvania, the species has experienced a slightly lower than average precipitation variation in the past 50 years.

Predicted micro sensitivity to changes in precipitation, hydrology, or moisture regime: Spotted turtles are seasonally dependent on wetland/aquatic habitats that may likely be drier due to climate change effects.

References:

Ernst, C.H., J.E. Lovich, and R.W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington and London.

Hulse, A.C., C.J. McCoy, and E. Censky. 2001. Amphibians and reptiles of Pennsylvania and the Northeast. Comstock Publishing Associates, Cornell University Press, Ithaca. 419 pp.

NatureServe. 2010. NatureServe central Databases. Arlington, Virginia. USA.

Species: Timber Rattlesnake (*Crotalus horridus*)
Global Rank: G4
State Rank: S3S4
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Very High

Habitat:

Timber rattlesnakes inhabit mountainous or hilly deciduous or mixed deciduous-coniferous forests, often with rocky outcroppings, steep ledges, and rock slides (Peterson and Fritsch 1986; Brown 1993; NatureServe 2010). Hibernacula are typically located in rocky areas where underground crevices provide shelter for overwintering. The historical range of the species extends from central New England southward to the Florida panhandle and westward through the eastern third of Texas. In the west, their range extends north through eastern Oklahoma, Kansas, and Nebraska and terminates in extreme eastern Minnesota. The species is absent from most of the Great Lakes states. In Pennsylvania, the range of the timber rattlesnake extends throughout the Ridge and Valley Province, the Laurel Highlands, and the more mountainous regions of the Allegheny Plateau (Hulse et al. 2001).

Current Threats:

Primary threats to the species include loss of habitat, habitat fragmentation and isolation of populations, and direct mortality caused by human persecution of the species and vehicles (NatureServe 2010).

Main Factors Contributing to Vulnerability Rank:

Although the timber rattlesnake may encounter anthropogenic barriers while trying to shift its range in response to climate change and occupies a rather specific habitat type within its range, the CCVI score of Not Vulnerable/Presumed Stable indicates that available evidence does not suggest that abundance and/or range extent within Pennsylvania will change substantially by 2050. The species may be less affected by climate change in the near future (2050) due to several life history characteristics such as the ability to physically move to new locations, more general dietary requirements (i.e., a variety of small mammals), and little dependence on specific moisture requirements during the spring and summer months. However, additional stressors that may affect the species are not considered in the CCVI and should be evaluated when planning conservation related activities.

References:

Brown, W.S. 1993. Biology, status, and management of the timber rattlesnake (*Crotalus horridus*): a guide for conservation. SSAR Herp. Circ. No. 22. vi + 78 pp.

Hulse, A.C., C.J. McCoy, and E. Censky. 2001. Amphibians and reptiles of Pennsylvania and the Northeast. Comstock Publishing Associates, Cornell University Press, Ithaca. 419 pp.

NatureServe. 2010. NatureServe central Databases. Arlington, Virginia. USA.

Petersen, R.C., and R.W. Fritsch, II. 1986. Connecticut's Venomous Snakes: The Timber Rattlesnake and Northern Copperhead. Second Edition. State Geol. Natural History Survey. Connecticut Bulletin 111: 48 pp.

Species: Wood Turtle (*Glyptemys insculpta*)
Global Rank: G4
State Rank: S3S4
State Wildlife Action Plan: Immediate Concern Species - Responsibility Species.
Climate Change Vulnerability: Not Vulnerable/Presumed Stable
Confidence: Moderate

Habitat:

A semi-aquatic species, the wood turtle can be found in a wide variety of terrestrial habitats as long as those habitats are near flowing water (Hulse et al. 2001). These habitats include deciduous forests, cultivated fields, woodland bogs, and marshy pastures (NatureServe 2010). The wood turtle occurs from Nova Scotia westward to eastern Minnesota. In the east, it ranges southward to the mountains of northern Virginia. In the western part of its range, its distribution is spotty to northeastern Iowa (Hulse et al. 2001). In Pennsylvania, the wood turtle is found throughout the state except in the southwestern corner (Hulse et al. 2001).

Current Threats:

The primary threats for this species include overcollection/exploitation, habitat destruction/alteration, water pollution, and highway fatalities (Hulse et al. 2001; NatureServe 2010).

Main Factors Contributing to Vulnerability Rank:

Although the wood turtle may encounter anthropogenic barriers in portions of its current distribution while trying to shift its range in response to climate change and an increase in the frequency and intensity of flooding of rivers and streams in late winter and early spring could potentially erode turtle hibernacula and expose them to the elements, the CCVI score of not vulnerable/presumed stable indicates that available evidence does not suggest that abundance and/or range extent within Pennsylvania will change substantially by 2050. The species may be less affected by climate change in the near future (2050) due to several life history characteristics such as the ability to physically move to new locations, dietary versatility, and habitat versatility. However, additional stressors that may affect the species are not considered in the CCVI and should also be evaluated when planning conservation related activities.

References:

Hulse, A.C., C.J. McCoy, and E. Censky. 2001. Amphibians and reptiles of Pennsylvania and the Northeast. Comstock Publishing Associates. Cornell University Press, Ithaca. 419 pp.

NatureServe. 2010. NatureServe Central Databases. Arlington, Virginia. USA.