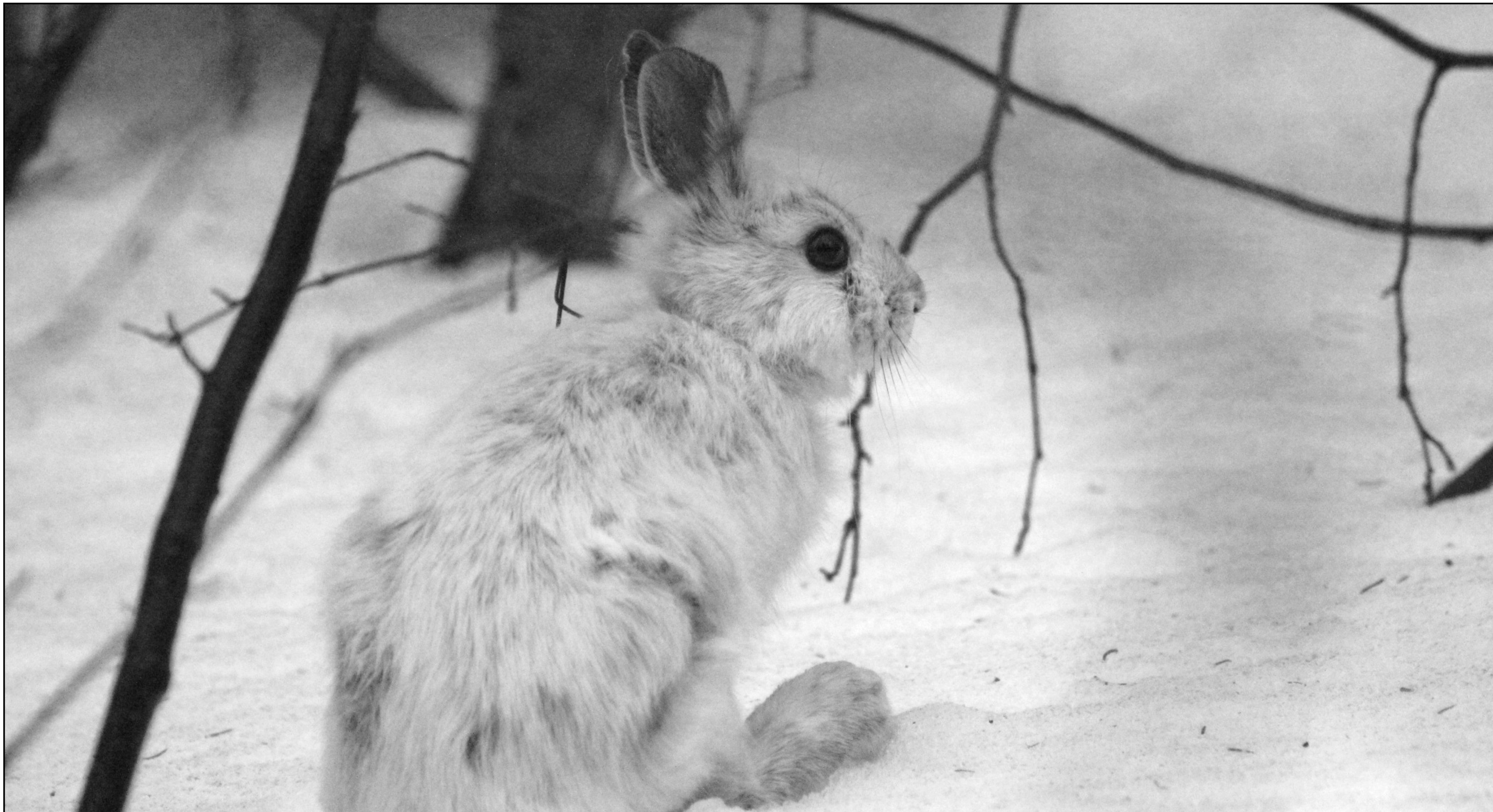

SNOWSHOE HARE VULNERABILITY ASSESSMENT

EASTERN UPPER PENINSULA, MICHIGAN

Inland Fish and Wildlife Department – Sault Ste. Marie Tribe of Chippewa Indians

Applied Forest and Wildlife Ecology Lab – Michigan State University

Funded by the United States Bureau of Indian Affairs – Tribal Climate Change Program

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SUMMARY – The System for Assessing the Vulnerability of Species

This assessment evaluates the vulnerability of snowshoe hares in the Eastern Upper Peninsula of Michigan using a tool called a System for Assessing Vulnerability of Species (SAVS) to Climate Change. In this context, vulnerability is based on three components: adaptive capacity (the potential for a species to reduce exposure or sensitivity to change), exposure (the degree to which a species will experience change), or sensitivity (the degree to which a species is actually affected; Glick et al. 2011). The SAVS assesses the relative impact of expected climate change effects for terrestrial vertebrate species using 22 different vulnerability response criteria that fall under the categories of habitat, physiology, phenology, and biotic interactions. The 22 criteria are used to create six major scores for the species and area being investigated: an overall score denoting level of vulnerability or resilience, four categorical scores (habitat, physiology, phenology, and biotic interactions) indicating source of vulnerability, and an uncertainty score, which reflects user confidence in the predicted response scoring. Scores are produced from a panel of experts and combined with information gathered from published materials.

It is important to note the SAVS is designed to first focus on the effects of climate change rather than integrating threats from other sources, and secondly, be applied by the user to a targeted region and time period encompassing a uniform set of climate predictions. One should also note that vulnerability assessments in general have an inherent level of uncertainty due to uncertainty in global carbon and nitrogen modeling, climate model downscaling, predicting species responses, and predicting biotic interactions.

More information on SAVS can be found on the USDA Forest Service website: http://www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/

CONTEXT and GOALS

The Tribal Climate Change Grant funded by the Bureau of Indian Affairs' Tribal Climate Change Program, provided funding for a vulnerability assessment on snowshoe hares in the Eastern Upper Peninsula (EUP) of Michigan to evaluate present climate change effects and future population vulnerability for purposes of writing a tribal action plan. The assessment was completed through a comprehensive literature review of Michigan and the Great Lakes region, along with responses to questions that were posed to a panel of experts on the 22 SAVS vulnerability criteria. Snowshoe hare are an important recreational and subsistence animal for the Sault Tribe of Chippewa Indians. Many tribal members hunt, view, and enjoy the snowshoe hare as local wildlife. The goal of the assessment was to determine sources of potential hare vulnerability in the Eastern Upper Peninsula with projected changes in climate.

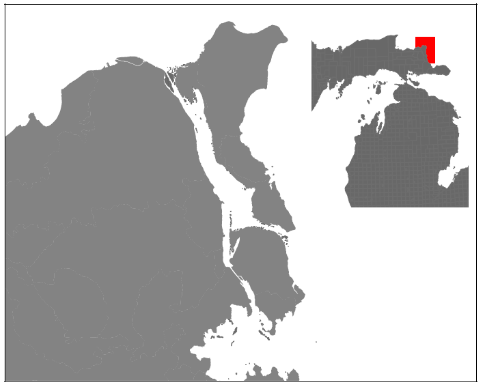

Figure 1. Assessment Area, Eastern Upper Peninsula of Michigan

CLIMATE CHANGE IN MICHIGAN

Michigan's climate has been warming, and the warming trend is accelerating. Despite uncertainty associated with climate predictions, the best available science indicates that the acceleration is likely to continue, and warming in the next 40 years will be roughly 10 times faster than the warming over the past 100 years in Michigan, regardless of attempts to curtail greenhouse gas emissions (Caldeira et al. 2003). The following climate information is taken from the Northwoods Climate Change Response Framework Project that stems from the USDA Forest Service's Northern Institute of Applied Climate Change (NIACS), which implemented the Michigan Forest Ecosystem Vulnerability Assessment and Synthesis. This report was a collaborative project among researchers, landowners, and managers. Headwaters Economics provides information on the Upper Peninsula's temperature change and fire activity.

The Michigan Forest Ecosystem Vulnerability Assessment and Synthesis used three different ecosystem models to predict climate change impacts on forests in the assessment area. The three different models represented a species distribution model (Climate Change Tree Atlas), a biogeochemical model (PnET-CN), and a forest simulation model (LANDIS-II). General Circulation Models (GCMs) are also used in long-term climate projections and short-term weather forecasting. Two scenarios are used under the GCMs, the A1F1 and the B1 scenario. The A1F1 projects the highest future greenhouse gas concentrations, resulting in the highest projected future warming. The B1 scenario projects the least future greenhouse gas concentration, resulting in the least projected future warming. Coupled with the A1F1 scenario was the National Oceanic and Atmospheric Administration (NOAA)'s Geophysical Fluid Dynamics Laboratory Model (GFDL). The GFDL is sensitive to changes in greenhouse gas concentration and therefore produces a higher-end projection, GFDL A1F1. Coupled with the B1 scenario is the Parallel Climate Model (PCM), which is less sensitive to greenhouse gas concentrations and therefore produces a low-end projection, PCM B1.

Change in Average Temperatures: Michigan, including the Eastern Upper Peninsula, is projected to warm substantially during the 21st century. Compared to the 1971 through 2000 baseline period, the average annual temperature is projected to increase 2.2 °F (1.2 °C) under the PCM B1scenario and 8.1 °F (4.5 °C) under the GFDL A1FI scenario by the end of the century. The projected temperature increase is not consistent across all seasons. Both models projected that winter months (December through February) will show dramatic warming by the end of the century (PCM B1: 2.5 °F, 1.4 °C; GFDL A1FI: 7.3 °F, 4.1 °C), but spring months (March through May) will experience less warming (PCM B1: 1.7 °F, 0.9 °C; GFDL A1FI: 6.0 °F, 3.3 °C). The GFDL A1FI scenario also projected an increase of 11.2 °F (6.2 °C) in summer temperatures by the end of the century. Summer warming is less severe under PCM B1 (2.2 °F). The hare vulnerability assessment area is projected to experience an average annual temperature increase of 1.3˚F under the PCM B1 scenario and 7.1˚F under GFDL A1F1 by the end of the century compared to the baseline period of 1971 to 2000. Minimum temperatures are projected to increase more than maximum temperatures under GFDL A1F1 and PCM B1, except for summer. Across the entire assessment area of the report, which includes 16.6 million acres across the Eastern Upper Peninsula and the Northern Lower Peninsula, temperatures have already increased and will continue to do so under all of the climate scenarios. It is also highly agreed upon with robust evidence that winter processes will change by having the highest temperature increase compared to all other seasons (Handler et al.

2014). Although the two climate scenarios project different amounts of warming, they are in agreement that mean, maximum, and minimum temperatures will increase in the assessment area across all seasons.

Maximum summer temperatures: Minimum temperatures are projected to increase more than maximum temperatures under both scenarios across nearly all seasons. Summer is the exception to this trend, with maximum temperature increases projected to be slightly greater than the projected increases in minimum temperatures under both scenarios.

Minimum winter temperatures: By the end of the century, winter minimum temperatures are expected to increase 3.5 °F (1.9 °C) under PCM B1 and 9.0 °F (5.0 °C) under GFDL A1FI.

Change in total annual precipitation: For the assessment area in Michigan, the PCM B1 scenario projects that the assessment area will receive 2.7 inches more annual precipitation at the end of the next century compared to the baseline years of 1971 through 2000. The GFDL A1F1 scenario projects an annual precipitation increase of around 1 inch for this same period.

Change in seasonal precipitation: Under the PCM B1 scenario, spring months are projected to receive 0.8 inches more precipitation over the 21st century, with all of the increase coming by mid-century. Summer precipitation under this scenario is projected to increase around 1 inch by mid-century. The GFDL A1FI scenario projects a much sharper distinction between these seasons, with spring precipitation gaining 2.7 inches and summer precipitation declining by 3.8 inches. Those projections represent a 37-percent increase from baseline spring precipitation, followed by a 39-percent decrease from baseline summer precipitation. Winter precipitation is expected to increase slightly for both scenarios. Fall precipitation is expected to decline slightly by the end of the century under the PCM B1 scenario (-0.3 inches), and fluctuate during the century under GFDL A1FI.

Changes to snowpack duration, amount and change to number of frost days: As winter temperatures increase across the assessment area, it is projected that more winter precipitation in northern Michigan will also be delivered as rain (Sinha and Cherkauer 2010). A study of neighboring Wisconsin presents several projected snowfall trends that may be applicable to the assessment area (Notaro et al. 2010). Researchers anticipated snowfall across Wisconsin to decline 31 percent under a low climate scenario and 47 percent under a high climate scenario by the end of the century. The largest reductions occurred in the early and late portions of the snow season, in November, March, and April. Under the same range of climate projections, the frequency of snowfall days is expected to decline between 41 and 54 percent. Finally, snow depth throughout the winter is expected to decline even more than snowfall amounts because snow depth will be reduced by warm temperatures between snowfall events. A study that attempted to integrate these opposing trends found that cold-season soil temperatures may increase between 1.8 and 5.4 °F (1 and 3 °C) and that there would be approximately 30 to 50 fewer soil frost days per winter on average across the assessment area by the end of the 21st century (Sinha and Cherkauer 2010). Total frost depth is projected to decline by 40 to 80 percent across the assessment area.

Projected drought duration and frequency: The potential for more frequent droughts and moisture stress during the growing season appears to be greater under the GFDL A1FI climate scenario. Even under the milder PCM B1 scenario, warmer temperatures may lead to increased transpiration and physiological stress. Even if seasonal precipitation increases slightly during the growing season, projected temperature increases may lead to net drier soil conditions due to changes in the ratio of evapotranspiration to precipitation.

Changes in potential, frequency and timing of flooding: There has been a trend toward more frequent flooding in river systems across the Midwest. A modeling study examining climate change effects on streamflow across the Midwest projected that runoff and streamflow may shift substantially across the assessment area in Michigan (Sinha and Cherkauer 2010). Researchers project that total winter runoff values may increase by more than 100 percent across the assessment area by the end of the 21st century, with the most dramatic increases occurring in the eastern Upper Peninsula as a result of winter melt events and winter rain. Spring total runoff is also projected to increase across a range of climate scenarios, and fall total runoff is projected to decline by 8 to 32 percent across the assessment area. Additionally, summer low flow levels may decrease even further, summer high flows may increase, and overall flashiness may increase in summer (Sinha and Cherkauer 2010).

Changes in frequency, severity, extent or timing of fire disturbances: Model simulations from around the world tend to agree that fire activity will increase by the end of the 21st century under climate change (Moritz et al. 2012). This agreement is particularly high for boreal forests, temperate coniferous forests, and temperate broadleaf and mixed forests. These global assessments correspond with more local research on climate and wildfire. Projections for boreal forests in Canada estimate that there may be a 100-percent increase in the annual area burned by the end of the century, along with a 50-percent increase in fire frequency (Flannigan et al. 2009). Research on boreal forest systems in Quebec projects that the wildfire season may shift later into the growing season, with wildfire risk doubling in August (Le Goff et al. 2009).

Changes in frequency, duration, extent or timing of extreme weather events (e.g., storms, heat waves): Studies from across the Midwest point to an increasing frequency of hot days across the assessment area, with roughly 20-30 more days per year above 95 °F (35 °C) and a greater frequency of multi-day heat waves by the end of the century (Diffenbaugh et al. 2005, Perera et al. 2012, Winkler et al. 2012). Downscaled climate scenarios also project that the Midwest will experience between 25 and 38 fewer days below freezing by the end of the 21st century (Sinha and Cherkauer 2010), and 12 to 15 fewer days that are colder than the current 95th percentile cold event (Diffenbaugh et al. 2005). Modeling studies indicate that there will be more days with weather conditions that support severe thunderstorms in the assessment area, particularly in summer months (Trapp et al. 2007). The timing of tornado season may continue to shift under future conditions, and tornadoes may occur farther north in areas where they have historically been uncommon.

Climate Change Impacts on Forests: The climate report suggests that tree species will be greatly affected by climate change. Many of the tree species that snowshoe hare utilize for cover or food resources are projected to decline or shift from current ranges. In the southern limit of their range, boreal and northern species are projected to decline for all three models that were evaluated (Tree Atlas, LANDIS-II, PnET-CN). Lowland conifers are projected to negative respond to projected climate changes as they have a moderate-low adaptive capacity, high-moderate vulnerability, with medium evidence and agreement for the assessment area. Northern hardwood species will also be vulnerable to frost due to shallow-roots. Under both climate scenarios, aspen habitat is projected to be more restricted in the Eastern Upper Peninsula. LANDIS-II projects that Balsam fir, Balsam poplar, Black ash, Black spruce, Eastern hemlock, Jack pine, Northern pin oak, Northern white-cedar, Paper birch, Red pine, White spruce, and Yellow birch will all decline by the end of the century.

Key Findings

- The assessment area is projected to experience an average annual temperate increase of 1.3˚F under the PCM B1 scenario and 7.1˚F under GFDL A1F1 by the end of the century compared to the baseline period of 1971 to 2000.
- In the assessment area, snowfall will decrease and rainfall will take its place.
- The report concludes that runoff could increase by over 100 percent, with most dramatic increases in the Eastern Upper Peninsula.
- LANDIS-II projects that Balsam fir, Balsam poplar, Black ash, Black spruce, Eastern hemlock, Jack pine, Northern pin oak, Northern white-cedar, Paper birch, Red pine, White spruce, and Yellow birch will all decline by the end of the century.
- Decline of aspen in Michigan.
- Increased fire activity and increased browsing by deer.

SAVS SCORES AND INTERPRETATIONS

Table 1: Vulnerability scores (overall and categorical) for snowshoe hares in the Eastern Upper Peninsula of Michigan. Vulnerability and uncertainty averages were derived from panel responses. Possible scores in each of the four categories (habitat, physiology, phenology, and biotic interactions) range from -5 to 5. Total vulnerability score range from -20 to 20. All uncertainty scores range from 0 to 1.

	Vulnerability Avg.		Uncertainty Avg.
HABITAT	**Low to High (-1 to 1)**		**Low to High (0 to 1)**
H1. Is the area or location of the general associated vegetation type used for breeding activities by this species expected to change?	**1.00**		**0.00**
H2. Is the area or location of the general associated vegetation type used for non-breeding expected to change?	**1.00**		**1.00**
H3. Are specific habitat components required for breeding expected to change within associated vegetation type?	**0.50**		**0.67**
H4. Are specific habitat components required for survival expected to change within associated vegetation types?	**0.83**		**0.17**
H5. Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	**1.00**		**0.17**
H6. What is the potential for this species to disperse?	**1.00**		**0.33**
H7. Does this species require additional distinct habitats during migration?	**0.00**		**0.50**
Habitat Total Positive, Total Negative, Total Uncertainty->	**5.33**	**0.00**	**2.84**
Habitat Vulnerability = (Positive total x [5/7]) + (Negative total x [5/6]) **Percent uncertainty for Habitat = (Sum of uncertainty scores / 7)**	**Habitat Score:** **3.81**		**Uncertainty Score:** **0.41**

	Vulnerability Avg.		Uncertainty Avg.
PHYSIOLOGY	**Low to High (-1 to 1)**		**Low to High (0 to 1)**
PS1. Are limiting physiological conditions expected to change?	**0.83**		**0.83**
PS2. Is sex ratio determined by temperature?	**0.00**		**0.17**
PS3. Are disturbance events that affect survival or reproduction expected to change?	**-0.67**		**0.50**
PS4. Is activity period expected to change?	**0.50**		**1.00**
PS5. Does this species employ adaptive strategies?	**0.33**		**0.50**
PS6. What is this species metabolic rate?	**0.17**		**0.17**
Physiology Total Positive, Total Negative, Total Uncertainty->	**1.83**	**-0.67**	**3.17**
Physiology Vulnerability = (Positive total x [5/6]) + (Negative total x [1]) **Percent uncertainty for Physiology = (Sum of uncertainty scores / 6)**	**Phys. Score:** **0.86**		**Uncertainty Score:** **0.53**

PHENOLOGY	**Low to High (-1 to 1)**		**Low to High (0 to 1)**
PH1. Does this species use temperature or moisture cues to initiate activities?	**0.83**		**0.33**
PH2. Are activities tied to discrete resource peaks that are expected to change?	**-1.00**		**0.50**
PH3. What is the separation between cues/activities and discrete events/ resources?	**1.00**		**0.67**
PH4. Does this species have more than one reproduction event per year?	**-1.00**		**0.00**
Phenology Total Positive, Total Negative, Total Uncertainty->	**1.83**	**-2.00**	**1.50**
Phenology Vulnerability = (Positive total x [5/4]) + (Negative total x [5/3]) **Percent uncertainty for Phenology = (Sum of uncertainty scores / 4)**	**Phen. Score:** **-1.05**		**Uncertainty Score:** **0.38**

	Vulnerability Avg.		Uncertainty Avg.
BIOTIC INTERACTIONS	**Low to High (-1 to 1)**		**Low to High (0 to 1)**
I1. Are important food resources for this species expected to change?	**0.50**		**0.50**
I2. Are important predator populations expected to change?	**0.17**		**0.33**
I3. Are populations of symbiotic species expected to change?	**0.00**		**0.00**
I4. Is prevalence of disease in this species expected to change?	**0.33**		**1.00**
I5. Are populations of important competing species expected to change?	**1.00**		**1.00**
Interactions Total Positive, Total Negative, Total Uncertainty->	**2.00**	**0.00**	**2.83**
Biotic Interaction Vulnerability = (Positive total x [1]) + (Negative total x [1]) **Percent uncertainty for Interactions = (Sum of uncertainty scores / 5)**	**Biotic Score:** **2.00**		**Uncertainty Score:** **0.57**
TOTAL VULNERABILITY SCORE	**Low to High (-20 to 20)**		**Low to High (0 to 1)**
Total Positive, Total Negative, Total Uncertainty->	**10.99**	**-2.67**	**10.34**
Overall Vulnerability Score = (Positive total x [20/22]) + (Negative total x [20/19]) **Percent of overall uncertainty = (Sum of uncertainty scores for all questions / 22)**	**Vuln. Score:** **7.18**		**Uncertainty Score:** **0.47**

SAVS Score Interpretation

According to the multiple criteria used by SAVS, snowshoe hare ranked moderately- to highly-vulnerable to climate change through the 21st century in the eastern upper peninsula of Michigan (overall score: 7.18, maximum possible score: 20.00). This score was highly uncertain (overall uncertainty: 0.47, maximum possible uncertainty: 1.00). Hare habitat was the most vulnerable category (section score: 3.81, maximum possible vulnerability: 5.00), followed by the biotic interactions category (section score: 2.00, maximum possible vulnerability: 5.00), physiology category (section score: 0.86, maximum possible vulnerability: 5.00), and phenology category (section score: -1.05, minimum possible vulnerability: -5.00).

Sources of high vulnerability (defined as a vulnerability score greater than or equal to 0.50) for hares included all criteria questions regarding habitat (area and distribution, habitat components, colonization abilities and transitional habitat criteria questions) except question H7, which asked about migration. Other high vulnerability criteria questions were PS1 (regarding limiting physiological thresholds), PS4 (changes to activity period), PH1 (using temperature or moisture cues to initiate activity), PH3 (separation of cues/activities and discreet events/resources), I1 (changes in important food resources), and I5 (changes in populations of important competing species).

Uncertainty scores were not incorporated into vulnerability scores in this assessment. Instead, uncertainty scores helped to identify the relative amount of information used to select responses in each category. Sources of high uncertainty (uncertainty scores greater than or equal to 0.50) are recommended for further research or literature investigations. These include H2: Is the area or location of the general associated vegetation type used for non-breeding expected to change? H3: Are specific habitat components required for breeding expected to change within associated vegetation type? H7: Does this species require additional distinct habitats during migration? PS1: Are limiting physiological conditions expected to change? PS3: Are disturbance events that affect survival or reproduction expected to change? PS4: Is activity period expected to change? PS5: Does this species employ adaptive strategies? PH2: Are activities tied to discrete resource peaks that are expected to change? PH3: What is the separation between cues/activities and discrete events/ resources? I4: Is prevalence of disease in this species expected to change? I5: Are populations of important competing species expected to change? Categorical uncertainty was lowest in the phenology category (0.38) followed closely by the habitat category (0.41), physiology category (0.53) and biotic interactions (0.57).

Sources of high uncertainty and high vulnerability (uncertainty scores greater than or equal to 0.50, vulnerability greater than or equal to 0.50) are priority areas for research. These include H2: Is the area or location of the general associated vegetation type used for non-breeding expected to change? H3: Are specific habitat components required for breeding expected to change within associated vegetation type? PS1: Are limiting physiological conditions expected to change? PS4: Is activity period expected to change? PH3: What is the separation between cues/activities and discrete events/ resources? I5: Are populations of important competing species expected to change?

There are three sources of climate resiliency (vulnerability scores below 0). These include PS3: Are disturbance events that affect survival or reproduction expected to change? PH2: Are activities tied to discrete resource peaks that are expected to change? And PH4: Does this species have more than one reproduction event per year? Resiliency in PS3 was determined mainly from the benefits of increased frequency of wildland fires. Resiliency in PH2 was attributed to the adaptive nature of hare fecundity when food and cover resources are in high supply, and PH4, hares have multiple litters per year.

SAVS Score Discussion

There was a general lack of information for questions on biotic interactions and physiological condition. Little information could be found in the published literature on the ability of hares to deal with heat extremes and drought in natural settings, and potential competitor and predator population changes, which included a suite of species. Perhaps most importantly, hares may be susceptible to a variety of emerging or likely increasing diseases, but few reports or studies have been completed on mortality rates from changing parasite or disease prevalence in a changing climate. Hares were generally regarded as both resilient due to their generalist foraging behavior, but highly vulnerable from phenological mismatch potential during spring molt, uncertainty in competitors such as white-tailed deer and cottontail rabbits, and uncertain dispersal ability.

As stated in Coe et al. (2012), there is much difficulty associated with determining the relative importance of different traits to survival of a species when exposed to a changing environment; criteria in the SAVS questionnaire each had equal, or roughly equal weight when in reality one or more criteria may exert a disproportionate influence on a species, such as habitat cover requirements for snowshoe hare. Each criterion should be evaluated for its potential contribution to vulnerability or resilience as a ranking among others. For example, the categorical score for phenology was considered resilient (-1.05), when phenological mismatch may be the most important factor contributing to sustainable hare populations at the southern range limit. Consideration of additional factors that influence the vulnerability of a species to climate change is paramount; this is especially true for species experiencing other anthropogenic stressors such as encroachment, invasive species, and hunting pressure. As stated by Coe et al. (2012), small differences in scores may or may not reflect large differences in actual vulnerability and should not be assumed to predict the relative probability of population decline. Rather, scores on individual questions should guide managers to sources of further investigation and management potential.

Appendix A: Literature Review in Support of Snowshoe Hare SAVS Rankings

Habitat: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
1. Area and distribution-breeding	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change? Specific habitat elements and food resources are considered in other questions	From Rowan and Keith (1956): litter size appears to be smaller in southern than in northern latitudes; comparatively small litters might be expected in Michigan and may change with respective changes in climate. Neonatal hares are very secretive, with littermates separating within a few days after birth to occupy hiding cover until fully weaned. This behavior likely reduces leveret predation risk. Mothers and littermates gather once per day at 1-2 hours after sunset to suckle for 2-10 min. After suckling, neonates and mothers separate, with neonates returning to hiding cover (Rongstad and Tester 1971; Graf and Sinclair 1987). Feldhamer et al. (2003): Hare cover requirements are best met among forests that are in the intermediate successional stages, typically those that are 20-25 years of age (Koehler 1990, Koehler and Brittell 1990). From the Michigan Vulnerability Assessment: High temperatures can influence forests in a variety of ways, and some tree species are limited by hot growing-season temperatures. Extreme temperatures may also be associated with disturbance events like droughts and wildfire. For the assessment area in Michigan, 10 of the 75 modeled species are projected to decline in suitable habitat under both the PCM B1 and GFDL A1FI scenarios. The projected declines in importance values are more severe for these species under GFDL A1FI than under PCM B1. Many of the species projected to decline are boreal or northern species near the southern limit of their range in the assessment area. Many of these species are widespread across the landscape, including characteristic species such as balsam fir, black spruce, jack pine, quaking aspen, and tamarack. Therefore, the reduction of suitable habitat for these species may affect a large portion of forested landscape in northern Michigan. Black spruce and white spruce are projected to have the most dramatic reductions in suitable habitat. Balsam fir, black ash, paper birch, and tamarack also have low modifying factor scores, suggesting that there are life-history traits or biological stressors that may cause these species to lose even more suitable habitat than the model results indicate. A projected reduction in suitable habitat at the end of the 21st century does not imply that these species will be extirpated or that mature, healthy trees will die. What this result indicates is that these species will be living farther outside their ideal climatic envelope and that these conditions may expose these species to greater stress. Living outside a suitable range also raises the risk of regeneration failure due to climatic factors.	**Vulnerability Score: 1** **Uncertainty: 0** This is an area of management need. This indicates the area used for breeding habitat is expected to decline or shift from current location. **Panel Comments:** A panel member stated, "Conifer types are sensitive according to draft ecological community analysis that Michigan Natural Features Inventory (MNFI) recently completed."

Habitat: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
2. Area and distribution-non-breeding	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Feldhamer et al. (2003): The snowshoe hare is common throughout the boreal and aspen parkland forests of Canada and Alaska. The range extends north to tree line and south into the coniferous forests of the Pacific coast, through the Cascade Mountains of Washington and Oregon, and into northern California and western Nevada (Orr 1933, 1934). The Midwestern distribution of snowshoe hare includes northern hardwood-coniferous forests in the Great Lakes region of Minnesota, Wisconsin, and Michigan. Eastern populations occur throughout the Maritime Provinces and New England, and into the mixed forests of the mountains of North Carolina, Virginia, West Virginia, and Tennessee. The central and northern distribution is largely continuous, whereas the discontinuity of forested habitat in the southern range results in disjunct distributions at lower latitudes. Some southeastern hare populations have declined or were extirpated during the last 50-100 years, and attempts at recovery have been largely unsuccessful (Fies 1991, 1993). The extent of the recent change in distribution along the southern range boundary is not well known. Current assessments indicate that northern forest ecosystems in the United States will undergo major northward shifts in range and a 40% to 80% reduction in geographical extent (Bachelet and Neilson 2000). Stands should be at least 8-10 ha for sustained snowshoe hare populations (Koehler and Brittel 1990; Keith et al. 1993). Both sexes have a home range of about 1.6-4.8 ha or 4-12 acres (Saunders 1988).	**Vulnerability: 1** **Uncertainty: 1** This is an area of research need and management need. This indicates the area used for non-breeding habitat is expected to decline or shift from current location.
3. Habitat components-breeding	Are specific habitat components required for breeding expected to change within the associated vegetation type?	A shortage of winter browse can affect the reproductive performance of females throughout the summer despite adequate spring herbaceous growth, which in turn affects the survival of juveniles in the summer (Vowles 1972, Vaughan and Keith 1981). Vowles (1972) also suggests that lightweight juvenile hares suffer high mortality during the transition period between and summer herbaceous diet and a fall diet of browse (Habitat Suitability Index Models: Snowshoe Hare, Carreker 1985). In upper Michigan, hares exhibit reproductive capabilities from late winter (February) to late summer (August) (Bookhout 1965a).	**Vulnerability: 0.50** **Uncertainty: 0.67** This is an area of research need. This indicates required breeding habitat components are expected to most likely decrease.

Habitat: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
4. Habitat components: non-breeding	Are other specific habitat components required for survival during non-breeding periods expected to change within the associated vegetation type?	Feldhamer et al. (2003): Overall, it appears that home range size of hares is related to several ecological factors, including food and cover availability, conspecific density, age, and perhaps sex. Home range size also seems inversely related to population density and thus per capita food resources. However, the role of food availability on home range size remains unclear, with conflicting results between food addition studies on the same site at different points in the hare population cycle (Boutin 1984; Hodges 1999). The mechanism apparently driving/underlying hare habitat choice is the preference for areas with substantial vegetative structure (Buehler and Keith 1982; Orr and Dodds 1982; Wolfe et al. 1982; Carreker 1985; MacCracken et al. 1988). Vegetation structure may consist of shrubs and/or immature trees, but must provide thermal shelter and particularly vertical and horizontal (depending on avian or terrestrial predators present) hiding cover from predators. Understory is the primary source of cover that is relevant to hares, but to a lesser extent overstory cover also may influence hare habitat use. Hare cover requirements are best met among forests that are in the intermediate successional stages, typically those that are 20-25 years of age (Cook and Robeson 1945; Dodds 1960; Parker 1984, 1986; Litviatis et al. 1985; Monthey 1986; Koehler 1990). In most cases, forage quantity is correlated with hiding cover availability and numerous studies have shown that selection for dense cover occurs regardless of plant species composition (Parker 1986; Rogowitz 1988; Ferron and Ouellette 1992; Thomas et al. 1997). The dominant force in habitat choice by hares surely is cover rather than food abundance, which implies that hares will forsake access to browse for the safety provided by vegetation. In Pennsylvania, hares selected areas with substantial amounts of coarse woody debris because of the cover it provided (Scott and Yahner 1989). Habitat use patterns by hares may shift in association with numerical changes in their abundance. Keith (1966) observed that hares remaining after a population decline were restricted to dense spruce forest stands to the exclusion of habitats providing less food. Similarly, Wolff (1980a), Fuller and Heisey (1986), and Hik (1995) observed that hares favored the thickest forest habitats when numbers were low, but expanded their distribution to include marginal habitat with sparser cover as densities increased. It may be that males use habitats with denser understory cover, whereas females occupy sites with greater forage availability (Litvaitis 1990). If hare population maintenance is an important factor in habitat management programs, it may be desirable to promote a high density of shrubs and immature trees, or to limit extensive timber harvest, fire suppression, or brush removal (Richmond and Chien 1976; Conroy et al. 1979; Buehler and Keith 1982).	**Vulnerability: 0.83** **Uncertainty: 0.17** This indicates required non-breeding habitat components are expected to decrease.

Habitat: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Feldhamer et al. (2003): Meslow and Keith (1971) reported that litter size was positively correlated with snow depth during the previous winter, likely due to increased access to high-quality food when snow accumulation allowed hares to access elevated browse. Hare cover requirements are best met among forests that are in the intermediate successional stages, typically those that are 20-25 years of age (Koehler 1990). Estimated stand density required to provide hares with adequate cover is reported to range from 11,590 to 33,210 stems/ha (Koehler 1990). It has been well documented that hares generally avoid open areas lacking vegetative structure (Murray et al. 1994). Hares may also occur in ecotones between various habitat types (Ferron and Ouellette 1992). Selection by hares for stands with tall understory plants also may be related to local snow accumulation during winter. Studies across the hare range have determined that they prefer habitats dominated by coniferous vegetation (Buehler and Keith 1982; Krenz 1988) whereas others suggest that deciduous cover is selected (Bailey 1946; Brooks 1955; Tompkins and Woehr 1979; Wolfe et al. 1982). Deciduous cover may be preferred during summer because of the role of leaves in reducing hare visibility to predators. It also appears that hares select habitats where food resources are clumped and cover is uniformly distributed within an individual's home range (Krenz 1988). In New Brunswick, hares select habitats with understory cover height ranging from 1 to 3 meters, whereas areas dominated by understory height less than 1 meter are not selected because such heights typically are exceeded by snow (Parker 1986). From the Michigan Forest Vulnerability Assessment: Boreal or northern tree species are expected to decline across Michigan including balsam fir, black spruce, jack pine, quaking aspen, and tamarack. Black spruce and white spruce are projected to have the most dramatic reductions in suitable habitat. Balsam fir, black ash, paper birch, and tamarack also have low modifying factor scores, suggesting that there are life-history traits or biological stressors that may cause these species to lose even more suitable habitat than the model results indicate.	**Vulnerability: 1.00** **Uncertainty: 0.17** This indicates projected changes are likely to negatively affect habitat features associated with improved reproductive success or survival.

Habitat: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Feldhamer et al. (2003): Although home ranges may be largely fixed for an individual's life span, home range shifts in excess of 400 m have been reported in several study areas (Adams 1959; O'Farrell 1965; Keith 1966). Hare populations can move seasonally from winter to summer home ranges based on snow accumulation and habitat change (Wolff 1980a; Wolfe et al. 1982). Keith et al. (1993) failed to detect a relationship between hare home range size and habitat quality in northern Wisconsin. Hare dispersal distances may range from several hundred meters up to 20 km (Aldous 1937; O'Farrell 1965; Windberg and Keith 1976; Gillis and Krebs 1999). Juveniles may disperse as early as 1 month of age and dispersal pulses for juveniles and adults seem to occur in the fall and spring. Experimental transplant of hares to new habitat to simulate dispersal has caused notable reductions in survival (Sievert and Keith 1985; Wirsing et al. 2002). Such results imply that loss of site familiarity and consequent increases in vulnerability to predation are important detrimental results of dispersal. In the southern portion of their range, hares may disperse at a high rate from areas having poor cover in search of sites with increased cover (Sievert and Keith 1985; Wirsing et al. 2002). Notable, hares transplanted from their home ranges exhibit homing and often return to their native home range (Keith and Waring 1956).	**Vulnerability: 1.00** **Uncertainty: 0.33** This indicates the species has a low ability to disperse.
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Hares may use small clearcuts for travel or feeding if intact stands are nearby and can occur in ecotones between various habitat types (Conroy et al. 1979; Monthey 1986; Scott and Yahner 1989; Thomas et al. 1997). From the Michigan DNR Wildlife Action Plan: In forests with logging activity, this species depends upon residual forested areas. Size of clearcuts does not seem to be important, however, the extent and configuration of the remaining forested areas does seem to be important (Potvin et al. 1999). A clustered distribution of clearcut patches may therefore be problematic for this species. At the population level, differences in adult survival in different stand structure types are sufficient to dampen population cycles in their southern range (Griffin and Mills 2009, Wirsing et al. 2002). Lewis et al. (2011) states, "In a fragmented forest in north-central Washington, pellet densities were associated primarily with density of large shrubs and saplings and medium trees within a stand. Pellet densities also were correlated positively with the amount of moist forest and correlated negatively with the amount of open-structured habitat within 300 m of the stand perimeter."	**Vulnerability: 0.00** **Uncertainty: 0.50** This indicates the species most likely has no additional habitats required that are separated from breeding and non-breeding habitats.

Physiology: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
1. Physiological thresholds	Are physiological thresholds related to temperature or moisture expected to change?	Feldhamer et al. (2003): Snowshoe hare fur provides effective insulation from inclement weather, although insulating properties vary by season, with winter fur being 30% more insulated than summer, whereas heat conductance is 35% greater in summer than winter. Hares seem to be more susceptible to hypothermia during cooler summer months than in winter. Lower critical temperatures are researched at 10 degrees Celsius in the winter compared to -5 degrees Celsius during winter (Hart et al. 1965). Hares may reduce radiant heat loss in winter through use of well-sheltered forms and snow burrows (Pietz and Tester 1983). Moisture thresholds are determined by food resources and vegetative moisture content. From The MI Forest Vulnerability Assessment: Compared to the 1971 through 2000 baseline period, the average annual temperature is projected to increase 2.2 °F (1.2 °C) under the PCM B1scenario and 8.1 °F (4.5 °C) under the GFDL A1FI scenario by the end of the century. The projected temperature increase is not consistent across all seasons. Both models project that winter months (December through February) will show dramatic warming by the end of the century (PCMB1: 2.5 °F, 1.4 °C; GFDL A1FI: 7.3 °F, 4.1 °C), but spring months (March through May) will experience less warming (PCM B1: 1.7 °F, 0.9 °C; GFDL A1FI: 6.0 °F, 3.3 °C). The GFDL A1FI scenario also projects an increase of 11.2 °F (6.2 °C) in summer temperatures by the end of the century. By the end of the century, winter minimum temperatures are expected to increase 3.5 °F (1.9 °C) under PCM B1 and 9.0 °F (5.0 °C) under GFDL A1FI.	**Vulnerability: 0.83** **Uncertainty: 0.83** This is an area of research need. This indicates projected changes in temperature and moisture are likely to exceed upper physiological thresholds
2. Sex ratio	Is sex ratio determined by temperature?	Generally, the sex ratio in snowshoe hare population is equal to 1 (Hodges et al. 2001). This species does not exhibit temperature dependent sex determination.	**Vulnerability: 0** **Uncertainty: 0.17**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods, etc.) that affect survival or reproduction expected to change?	From the MI Forest Vulnerability Assessment: There are clear winter precipitation gradients across the assessment area, decreasing from north to south in the eastern Upper Peninsula and decreasing from west to east in the northern Lower Peninsula (ClimateWizard 2012). These trends are dictated by the prevailing wind direction, topography, and lake-effect snow from Lake Superior and Lake Michigan. From 1900 to 1990, there was an increase in snowstorms of 6 inches or more across the upper Midwest (CCSP 2008). In the upper Midwest, there was a 50-percent increase in the frequency of days with rainfall of 4 inches or more during the 20th century (CCSP 2008). Studies from across the Midwest point to an increasing frequency of hot days across the assessment area, with roughly 20-30 more days per year above 95 °F (35 °C) and a greater frequency of multi-day heat waves by the end of the century (Winkler et al. 2012). Simulations from around the world tend to agree that fire activity will increase by the end of the 21st century under climate change (Moritz et al.2012). This agreement is particularly high for boreal forests, temperate coniferous forests, and temperate broadleaf and mixed forests. Fire could have a greater influence because it can be a catalyst for change in vegetation, perhaps prompting more rapid change than would be expected based only on the changes in temperature and moisture availability Bryant et al. (2009) states, "Because fire initiates secondary forest succession, a fire mosaic creates variation in the abundance of early successional plants that snowshoe hares eat in winter…" In Northwest regions, fire actually made an unpalatable tree species (black spruce) palatable to snowshoe hares (Carreker 1985). Fox states, "Fires set in motion plant succession, potentially leading to an increase in snowshoe hares (Grange 1965). In severely burned sites, snowshoe hare populations did not thrive, but a couple of summers after disturbance events, snowshoe hares began to revisit due to understory regrowth (Keith and Surrendi 1971). Pregnancy rates and juveniles were lower on the severe burn site (Keith and Surrendi 1971). Disturbances and fire can allow hares to survive in mature forests in a small population (Carreker 1985).	**Vulnerability: -0.67** **Uncertainty: 0.50** This indicates projected changes in disturbance events will likely increase survival or reproduction A panel member stated, "Hares are boreal and early successional. Early successional boreal forest is created largely through fire (also insect outbreaks).

Physiology: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	From Feldhamer et al. (2003): Hares are predominantly active at dawn and dusk (Keith 1964; Mech et al. 1966; Foresman and Pearson 1999), and usually venture only at night to feeding areas that may lack substantive cover. Hare activity patterns may also vary seasonally, with animals typically spending more time foraging when temperature and wind speed are low or barometric pressure is high (Théau and Ferron 2000, 2001). Hares dig craters during winter to gain access to plants found beneath the snow (Gilbert 1990), and such activities are less common during full moon, presumably because of higher predation risk (Gilbert and Boutin 1991). This suggests that hares forage in a manner that is highly sensitive to predation risk; cover is most likely the driving factor in hare daily activity periods.	**Vulnerability: 0.50** **Uncertainty: 1.00** This is an area of research need. May indicate hares are likely to exceed upper physiological thresholds.
5. Survival during resource fluctuation	Does this species have alternative life history pathways to cope with variable resources or climate conditions?	Feldhamer et al. (2003): Snowshoe hare fur provides effective insulation from inclement weather, yet its insulative properties vary seasonally. Fur is approximately 30% more insulative during winter than summer, whereas heat conductance is 35% greater during summer than winter (Hart et al. 1965). Metabolic activities also undergo seasonal changes, with increased metabolism and altered epinephrine and norepinephrine production during winter (Feist and Rosenmann 1975; Hart et al. 1965). These changes may be important in regulating shivering thermogenesis because hares appear to be more susceptible to hypothermia during summer. It was estimated that lower critical temperatures are reached at 10 degrees Celsius during summer, compared to -5 degrees Celsius during winter (Hart et al. 1965). Hares may reduce radiant heat loss in winter through use of well-sheltered forms and snow burrows (O'Farrell 1965; Pietz and Tester 1983). In captivity, snowshoe hare allegedly experience reduced oxygen uptake during winter, which apparently coincides with a 16% reduction in caloric intake (Hart et al. 1965). This finding may suggest that in the wild snowshoe hare activity and/or metabolic rates decrease in response to cold temperatures. Hares have multiple litters per year and litter size is co-dependent on food uptake.	**Vulnerability: 0.33** **Uncertainty: 0.50** Indicates flexible strategies to cope with variable resources across A panel member stated: “Snowshoe hares are adapted to feast or famine depending on fire and ecological succession.
6. Energy requirements	What is this species' metabolic rate?	Research found that the daily metabolism for Michigan reproductive females is estimated to be about 321.2 Kcal/Kg$^{0.75}$ (Belvosky 1984). In Michigan, snowshoe hare use 219 g WM/Kg/day in captivity (Ellsworth and Reynolds 2006). The field metabolic rate in late winter for a snowshoe hare is 740kJ/Kg/day, in which the hare needs to consume about 230g WM/Kg/day or 25% body mass to meet this energy (Ellsworth and Reynolds 2006). Summertime energy requirements were about 110 Cal/Kg$^{0.75}$ /day, with reproductive hare's food requirements elevated (Ellsworth and Reynolds 2006).	**Vulnerability: 0.17** **Uncertainty: 0.17** Moderate (e.g. most endotherms)

Phenology: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
1. Mismatch potential-cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, and breeding)?	Feldhamer et al. (2003): During winter, snowshoe hare pelage is almost pure white, except for black-tipped ears and grayish feet (Grange 1932; Doutt et al. 1967). The seasonal change in snowshoe hare pelage color likely is a result of natural selection favoring cryptic coloration, where the timing of the molt is correlated with the occurrence of snow cover (Nagorsen 1983). Snowshoe hares undergo molts during the spring, late summer, and mid-autumn (Lyman 1943), although major molts occur during spring and fall. The vernal molt begins in March-April, and the autumnal molt commences in late September. Molting usually is complete after 70-90 days, and females tend to molt more rapidly than males (Grange 1932; Severaid 1945). Photoperiod and corresponding changes in hormonal profiles are closely associated with onset of molting. Molting is controlled by altered levels of pituitary gonadotropins, which are influenced by seasonal changes in photoperiod. Increased levels of gonadotropins result in brown pelage, whereas reduced gonadotropin induces white coloration (Lyman 1943). Zimova et al. (2014) observed nearly 200 snowshoe hares across a wide range of snow conditions and two study sites in Montana, and found minimal plasticity in response to mismatch between coat color and background. Zimova et al. (2014): "We found that molt phenology varied between study sites, likely due to differences in photoperiod and climate, but was largely fixed within study sites with only minimal plasticity to snow conditions during the spring white-to-brown molt. We also found no evidence that hares modify their behavior in response to color mismatch. Hiding and fleeing behaviors and resting spot preference of hares were more affected by variables related to season, site and concealment by vegetation, than by color mismatch. We conclude that plasticity in molt phenology and behaviors in snowshoe hares is insufficient for adaptation to camouflage mismatch, suggesting that any future adaptation to climate change will require natural selection on molt phenology or behavior." From the Michigan Vulnerability Assessment: Studies have shown that across much of the Midwest, an increasing percentage of winter precipitation is being delivered as rain rather than snow (Feng and Hu 2007, Notaro et al. 2011). This shift from snowfall to rainfall is strongly correlated with winter wet-day temperatures. As winter temperatures increase across the assessment area, it is projected that more winter precipitation in northern Michigan will also be delivered as rain (Sinha and Cherkauer 2010). Total snow water equivalent (the amount of water contained in the snowpack) is projected to decrease between 40 and 80 percent by the end of the century under a range of climate scenarios (Sinha and Cherkauer 2010). Areas that typically receive lake-effect snow may receive increased snow during the early part of the 21st century while winter temperatures remain cold enough and ice cover on the Great Lakes continues to decrease (Burnett et al. 2003, Wright et al. 2013). Under the same range of climate projections, the frequency of snowfall days is expected to decline between 41 and 54 percent. Finally, snow depth throughout the winter is expected to decline even more than snowfall amounts, because snow depth will also be reduced by warm temperatures between snowfall events.	**Vulnerability: 0.83** **Uncertainty: 0.33** This is an area of strong research need. This indicates that the species primarily uses temperature or moisture cues to initiate activities. A panel member stated, "I read recently that hare populations can shift to shorter white periods on the scale of time over which snow decreases. But I cannot find the reference, and they clearly do use photoperiod as the primary cue."

Phenology: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
2. Mismatch potential-event timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Snowshoe hare do not have specific events that are timed to certain resource peaks. Breeding last from January to October. It is not clear that changes in the timing of precipitation and increases in temperature would alter the timing of food resources availability and abundance or predation pressure, and, hence, fecundity. Snowshoe hares will also have a rise in metabolism, epinephrine and norepinephrine in winter, which could be crucial in regulating shivering thermogenesis (Murray 2003). Feldhamer et al. (2003): Hare activity patterns may vary seasonally, with animals typically spending more time foraging when temperature and wind speed are low or barometric pressure is high (Théau and Ferron 2000, 2001). From the Michigan Vulnerability Assessment: Growing seasons are dictated by a variety of factors, including day length, air temperatures, soil temperatures, and dates of first and last frost (Linderholm 2006). Therefore, a variety of metrics can describe how growing seasons may continue to change under a range of climate scenarios. A study covering the entire Midwest examined the changes in dates for the last spring frost and first fall frost under a range of climate scenarios (Wuebbles and Hayhoe 2004). This study projected that the growing season will be extended by 30 days under the B1 emissions scenario and 70 days under the A1FI scenario by the end of the century. The last spring frost dates are projected to shift earlier into the year at approximately the same rate that first fall frost dates will retreat later into the year.	**Vulnerability: -1.00** **Uncertainty: 0.50** This indicates there is no temporal variation in resources, or the species breeds year-round A panel member stated, "I would say that snowfall influences survival and provides a refuge from predation. And snowfall comes in pulses that are climate sensitive". The panel discussed this particular question and came to a conclusion that there is no temporal variation in resources or breeds year round.
3. Mismatch potential-proximity	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Snowshoe hare do not have critical resource event timings such as resources for migration or the dependence on resources for single, major breeding events that occur spatially or temporally distant from cues, i.e. opportunistic, non-migratory breeders vs. migratory species with one breeding event. Here the panel was in agreement that critical resources occur far in advance or in distant locations from cues or initiation of activity; with high uncertainty.	**Vulnerability: 1.00** **Uncertainty: 0.67** This indicates critical resource occurs far in advance or in distant locations from cues or initiation of activity. This is an area of research need. This is an area that should be revisited by the panel to clarify the question.

Phenology: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
4. Resilience to timing mismatch	Does this species have more than one opportunity to time reproduction to important events?	During March-April, 11-91% of snowshoe hare are pregnant (Murray 2003). Gestation is between 37-38 days in New York (Murray 2003). Different research has found different beginning and ending times to breeding, lasting 7 months (March-September; Murray 2003), to 10 months (January to October; Ellsworth and Reynolds 2006). Regardless of the beginning and ending period, it is known that snowshoe hare have a lengthy breeding season and can breed multiple times a year (up to four litters). Snowshoe hare have two uteri, which can allow them to have prenatal growth of one litter, while the onset of another is developing. Snowshoe hare do not rear their young for a long period of time (up to 2 weeks).	**Vulnerability: 0** **Uncertainty: 0** This indicates the species reproduces once or multiple times per year

Biotic Interactions: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
1. Food resources	Are important food resources for this species expected to change?	From Feldhamer et al. (2003): Hares are herbivorous, and rely mainly on leafy vegetation during summer and woody browse during winter. Hares begin feeding on leafy foods shortly after spring greenup and remain on this diet until after the first frost. During summer, hare diets include such foods as grasses (Graminae), sedges (Cyperaceae), ferns (Polypodiaceae), and forbs (Aldous 1936; Dodds 1960; Bider 1961; Mozejko 1971). In Nova Scotia, winter diets included principally blueberry (*Vaccinium* spp.), maple (Acer spp.), and balsam fir (*Albies balsamea*) in one study area (Dodds 1987), and spruce (*Picea* spp.), birch, and maple in another (Telfer 1972). In Newfoundland, winter diet consists of birch, fir, and spruce (Dodds 1960). In Pennsylvania, the winter diet consists of raspberry (*Rubus* spp.), maple (*Acer pennsylvanicum*), and birch (*B. alleghaniensis*) (Brown 1984; Scott and Yahner 1989). Appalachian hare populations appear to rely extensively on cranberry (*Vaccinium erythrocarpum*) (Brooks 1955), whereas those in Oregon select disproportionately red huckleberry (*V. parvifolium*) (Mozejko 1971). In Minnesota, birch, willow, and aspen formed the bulk of winter-spring snowshoe hare diets (Aldous 1936), whereas in Ontario, maple, aspen, prune (*Prunus* spp.), shepherdia (*Shepherdia canadensis*), and hazel (*Corylus cornuta*) were heavily used, and larch (*Larix laricina*) and spruce were only lightly browsed (de Vos 1964). Overall, hares tend to prefer browse from deciduous rather than coniferous species (Bookhout 1965c; Klein 1977; Bryant and Kuropat 1980; Bryant 1981). Hares browse twigs <4 mm in diameter, although twigs up to 1 cm may be browsed and saplings and mature trees may be girdled if food availability is limited (de Vos 1964; Vowles 1972; Wolff 1980a; Pietz and Tester 1983). Hares experience low digestibility and thus fail to maintain weight on a coarser browse. Hare dietary preferences may be related to a variety of factors, including plant composition, palatability, and digestibility. Typically, winter browse has <10 % protein content (Walski and Mautz 1977; Pease et al. 1979; Pehrson 1984; Rogowitz 1988, Wirsing and Murray 2002), which apparently is inadequate to maintain hare body mass (Sinclair et al. 1982; Sinclair and Smith 1984). Intermediate levels of crude protein in the diet (16-20%) are associated with maximum digestibility in hares (Holter et al. 1974), and free ranging animals may forage selectively on specific plant parts or plant species so as to maximize protein intake. Highest protein content tends to occur in the buds and finer twigs of deciduous woody browse (Grigal and Moody 1980). Winter browse also may have low energy (<6.0 kcal/dry g) and high fiber (27-32%) content, both of which could contribute to food being a limiting resource (Walski and Mautz 1977; Pease et al. 1979; Pehrson 1984; Rogowitz 1988). A suite of plant secondary compounds may act as feeding deterrents or be toxic to hares, including carbon-based phenolics and terpenes that are contained primarily in the defensive secretions of evergreens. Feeding experiments have shown that hares will voluntarily reduce their food intake rates well below maintenance levels when fed browse heavily defended by these chemicals (Reichardt et al. 1984; Sinclair et al. 1988). It follows that in the field hares may be forced to avoid defended species unless alternatives are rare. Under conditions of natural browse limitation or low browse diversity, hares may incur notable fitness costs because they necessarily must select a diet made up largely of heavily defended foods. Tree species anticipated to expand their ranges northward in the assessment area are predominantly deciduous species, such as red maple, sugar maple, and red oak.	**Vulnerability: 0.50** **Uncertainty: 0.50** This is a subject area of strong research need. This indicates primary food source(s) are expected to be somewhat negatively impacted by projected changes

Biotic Interactions: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
2. Predators	Are important predator populations for this species expected to change?	The Canadian Lynx is an important predator for the snowshoe hare and their cycles even correlate with the 10-year cycle of a snowshoe hare. Snowshoe hare are the lynx's predominant prey (O'Donoghue et al. 1998). In the assessment area lynx populations are extirpated, yet the snowshoe hare is prey to many other predators. From Feldhamer et al. (2003): An experiment designed to evaluate the effects of predation risk on hares (Hik 1995) determined that during a natural population decline caused mainly by predation, average mass of females declined despite an apparent abundance of winter forage. Concurrently, hares found in study areas where terrestrial predators were excluded maintained body mass. The mechanism for such differences seems to be the impact that perceived predation risk has on hare foraging behavior. The predominant hypothesis for the lower densities and increased stability observed among southern hare populations is related to the effects of strong and consistent predation by a suite of facultative and generalist predators, combined with the greater patchiness of suitable hare habitat (Wolff 1980a, 1981). Under this model, hares are heavily and continuously preyed on by several predator species that are less abundant at higher latitudes. Southern predators can rely extensively on alternate prey and thus do not respond numerically to hare population declines as seen at higher latitudes. Thus, predators should exert a more consistently heavy rate of predation on southern hare populations. It follows that greater discontinuity of suitable hare habitat in the EUP may cause dispersing hares to experience high predation, thereby further limiting population increase and expansion. Empirical support for this hypothesis comes from short-term studies showing restricted movements and high mortality among hares residing in small patches of suitable habitat along the southern range boundary (Dolbeer and Clark 1975; Buehler and Keith 1982; Sievert and Keith 1985; Keith et al. 1993). Keith et al. (1993) and Wirsing et al. (2002) have failed to detect higher predation rates among naturally dispersing individuals, leading to speculation that high on-site predation in suitable hare habitat, instead of high predation rates among dispersers may be the principle population-stabilizing mechanism. The possibility that overwinter food abundance or food quality limits hare populations at lower latitudes is not supported, given the similar reproductive outputs observed between populations in suitable and marginal habitat (Kuvlesky and Keith 1983) and across a latitudinal gradient (Murray 2000). Predation is the overwhelming proximate cause of death in snowshoe hares (Morse 1939; Brand et al. 1975; Keith et al. 1984, 1993; Boutin et al. 1986; Murray et al. 1997). Mammalian and avian predators commonly kill hares, with total losses from predation > 75% among all studies where a sample of animals was monitored intensively via telemetry for cause of death. Predation can be the proximate cause of death for >80% of leverets (O'Donoghue 1994; Hodges et al. 2001). The most common mammalian predators of post-weaning juvenile and adult hares (along with projected population changes with a warming climate according to Hoving et al. 2013): coyote (*Canis latrans,"increase likely"*), and fisher (*Martes pennant, "presumed stable"*) and Lynx (*Lynx Canadensis, "highly vulnerable")*. Less common predators include bobcat (*Lynx rufus "increase likely"*), wolf (*Canis lupis, "presumed stable"*), red fox (*Vulpes vulpes, "increase likely"*), black bear (*Ursus americanus, "presumed stable"*), marten (*Martes Americana "moderately vulnerable*), weasel (*Mustela erminea, M. frenata, "presumed stable"*), mink (*Mustela vison, "presumed stable"*), barred owl (*Strix varia, not listed*), and raven (*Corvus corax, not listed*). Hare behavior and hare population dynamics are strongly influenced by predation, as shown in Griffin et al. (2005), where hares move significantly less but experience higher levels of mortality when illuminated by a full moon and they tend to avoid risky canopy gaps in closed forest types during this time (Hodson et al. 2010). EUP hare populations most likely face a variety of generalist predators; all of which are either presumed stable or likely increasing in population with a changing climate, except for American marten. (Hoving et al. 2013)	**Vulnerability: 0.17** **Uncertainty: 0.33** This indicates primary predator(s) are expected to be somewhat positively impacted by projected changes Panel Member Comments: "I have published several papers on lynx habitat at the southern edge of their range. East UP has too little early successional habitat and too little connection to viable lynx populations to have a viable lynx population. I think lynx are out of the picture for east UP, but snowshoe hare are a significant prey item for marten, fisher, fox, coyote, bobcat, and wolves. They are eaten by many species; some predators will be sensitive to climate change (lynx, marten) but others will benefit from warmer temperatures (coyote, fox, bobcat). The primary predator is probably bobcat."

Biotic Interactions: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
3. Symbionts	Are populations of symbiotic species expected to change?	No indication of symbiotic relationship was found in Feldhamer et al. (2003).	**Vulnerability: 0.00** **Uncertainty: 0.00** This indicates the species has no symbiotic species, or symbiotic species are not affected by projected changes
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Feldhamer et al. (2003): Hare body mass may be related to levels of parasitism (Keith et al. 1985; Keith and Cary 1990; Murray et al. 1998). In Alberta, heavy tick infestation among female hares apparently was associated with litter size reductions (Keith and Cary 1990). Several species of ectoparasite have been associated with hares including rabbit ticks and Rocky Mountain wood ticks (commonly found near the facial region), whereas larvae and nymphs may occur anywhere on the body (Phillip 1938; Dodds and Mackiewicz 1961). Other ectoparasites include fleas and blackflies. Helminths infecting hares include several species of nematodes, cestodes, and trematodes, most of which are found in the gastrointestinal tract or lungs. A stomach worm (*Obeliscoides cuniculi*) with a direct life cycle is common among hares throughout much of the species's range (Manweiler 1938; Erickson 1944; Dodds and Mackiewicz 1961; Bookhout 1971; Bloomer et al. 1995). From the Michigan Forest Ecosystem Assessment: Many invasive species, insect pests, and pathogens will increase or become more damaging, including tick species (limited evidence, high agreement). Brownstein et al. (2005) projects an increase in suitable habitat for the Lyme disease carrying tick species, *Ixodes scapularis*, of 213% by 2080. There is little information on the spread of these parasites with a changing climate in Michigan.	**Vulnerability: 0.33** **Uncertainty: 1.00** This is an area of research need. This indicates disease prevalence is expected to increase with projected changes.

Biotic Interactions: Snowshoe Hare			
Trait/Quality	**Question**	**Background info. & explanation of score**	**Answer/Uncertainty**
5. Competitors	Are populations of important competing species expected to change?	Species composition and size and height classes of browse consumed by snowshoe hares may cause dietary overlap and potential competition with moose (Dodds 1960; Wolff 1980b) or deer (Hough 1949; Telfer 1972). However, hares and ungulates do not always compete for food despite considerable dietary overlap, either because of food superabundance or differential use of browse height classes (Bookhout 1965b, 1965c; Oldemeyer 1983). In some areas, hares may benefit from porcupine (*Erethizon dorsatum*) feeding activities by consuming unbrowsed twigs that have been clipped by the latter species and have fallen onto the ground (Ferguson and Merriam 1978). From the Michigan Vulnerability Assessment: A study of small mammal populations across northern Michigan documented large range shifts among nine species that have northern or southern range limits within the assessment area (Myers et al. 2009). Southerly species such as white-footed mice, eastern chipmunks, southern flying squirrels, and common opossums were found to be expanding their ranges northward across the assessment area since 1980, in some cases by as much as 150 miles. Northern species such as woodland deer mice, southern red-backed voles, woodland jumping mice, least chipmunks, and northern flying squirrels declined in relative abundance across the assessment area. In many cases, the proportion of southern mammal species appears to have increased substantially during the 20th century, replacing their northern counterparts in some locations. A change in small mammal communities has the potential to affect the function and composition of forest communities in northern Michigan. Changes in snowfall amount and duration throughout the assessment area are projected to affect the wintertime foraging behavior for main competing herbivores such as moose and white-tailed deer. Climate change is expected to favor white-tailed deer and reduce populations of moose throughout the assessment area (Frelich et al. 2012, Hoving et al. 2013, Rempel 2011). Warmer winter temperatures and reduced snow depth may lower the energy requirements for deer, and increase access to forage during winter months (Wisconsin Initiative on Climate Change Impacts Wildlife Working Group 2011). Conversely, warmer temperatures appear to cause greater physiological stress and parasite loads in moose. If deer populations increase over the 21st century, this herbivore could have even greater impacts on forest vegetation across the assessment area than it already has. Research has found that deer browsing pressure may limit the ability of forests to respond to climate change (Fisichelli et al. 2012). Tree species anticipated to expand their ranges northward in the assessment area, such as red maple, sugar maple, and red oak, are browsed much more heavily than boreal conifers such as balsam fir and white spruce. Deer herbivory may also favor species that are not browsed heavily, such as ironwood and black cherry, or invasive species like buckthorn or Japanese barberry. Tree Atlas, LANDIS-II, and PnET-CN project that most mesic hardwood species and eastern white pine will gain in suitable habitat, biomass, and productivity in the assessment area during the 21st century, but none of these models accounts for herbivory.	**Vulnerability: 1.00** **Uncertainty: 1.00** This is a subject area of high research need. This indicates major competitor species are expected to be positively impacted by projected changes.

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