Species Status Assessment
Report for the
American Hart's-tongue Fern
(*Asplenium scolopendrium* var. *americanum*)
Version 1.3

American Hart's-tongue Fern (photo credit: Alan Cressler, USGS).

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EXECUTIVE SUMMARY

This report summarizes the results of a species status assessment (SSA) conducted for the American hart's-tongue fern (AHTF) (*Asplenium scolopendrium* var. *americanum*). The AHTF was listed as a threatened subspecies in 1989. The results of this report will inform the next 5-year review for the species and help determine whether the AHTF is correctly classified as a threatened subspecies. As part of the 5-year review, the Service will also assess how well the Recovery Plan currently describes recovery for the species.

The SSA report, the product of conducting a SSA, is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. Using the SSA framework, we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (the 3Rs) (Smith et al. 2018, p. entire). For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in natural ecosystems within a biologically meaningful timeframe. A core team of biologists from across the species' range (see Acknowledgments) participated in this SSA to determine the key concepts of viability and the assessment using the 3Rs.

The AHTF is a rare, North American variety of a widespread species that is most abundant in Europe and Eurasia. The AHTF is a perennial, evergreen fern, closely associated with cool, moist refugia on dolomitic limestone bedrock under intact deciduous hardwood canopies with shallow soils and an open understory. The AHTF is distributed from central New York, through south central Ontario, and northern Michigan on glacially modified escarpments in areas of heavy lake-effect snowfall. Disjunct populations occur in sinkhole environments in Tennessee and Alabama. While known to be extant in Mexico, these populations are not addressed in this SSA due to a lack of readily available information.

In order to have resilient populations, the AHTF needs sufficiently large populations, with stable or increasing number of individuals (i.e., trend) and all life stages present, and adequate moisture (i.e., cool/moist microclimate, well-drained), substrate (i.e., deciduous canopy, low herbaceous cover), light (i.e., crevices, soil depth, High Mg limestone bedrock), and freeze/thaw buffer (i.e., winter snowpack, geothermal buffering) conditions. Based on over 100 years of survey data for the AHTF in New York, the core team determined that populations greater than 400 individuals are most resilient to stochastic changes in the environment, populations with 100 to 400 individuals are moderately resilient, and populations less than 100 individuals are least resilient. Invasive species compete with the AHTF for available substrate and light resources as well as degrade their quality.

Since the AHTF was originally listed, the number of known extant populations of AHTF increased in published reports, prior to this SSA, from 16 populations in the U.S. consisting of a few thousand individuals to 139 populations in the U.S. and Canada consisting of a little over a hundred thousand individuals. Currently, there are 144 extant populations/Environmental Occurrences (EOs), 32 in the U.S. and 112 in Canada across 177-recorded populations/EOs. We conservatively estimate the total population of the AHTF to be approximately 122,000 plants, although the lack of recent surveys at 81 populations in Ontario and 1 population in Michigan that we believe to represent approximately 48,000 plants, increases our uncertainty for approximately 40 percent of the estimate.

In this SSA, we have utilized the most recent and best available scientific data to evaluate population resiliency for the AHTF in the U.S. and Canada (Table 0-1, Table 0-2). Of the 177 recorded populations/EOs, 11 populations are considered Historical by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and 22 populations have been extirpated since surveys began for the species. Six of the 22 populations were extirpated in the 1920s and 1930s in New York and Ontario, primarily due to quarrying and logging, and 12 additional populations were extirpated from the 1960s through the 1990s, primarily due to logging and development activities in Ontario. Recent losses consist of three small populations in New York, Michigan, and Alabama since the mid-2000s. Additionally, 27 populations are considered extant but do not have any available survey data and are considered "Unknown." Therefore, we ranked the resilience of 117 populations of the AHTF. We found that among the 117 populations assessed, 30 populations (26 percent) were ranked High, 57 populations (49 percent) were ranked Medium, and 30 populations (26 percent) were ranked Low. Our assessment of current condition is well-informed in the U.S.; however, higher uncertainty exists regarding the populations in Ontario where fewer populations have readily available abundance and habitat information.

Approximately 107,000 plants (88 percent) are located in populations with a High condition and approximately 13,000 plants (11 percent) are located in populations with a Medium condition. Approximately 900 plants are found in the 30 Low condition populations. Four populations in Ontario have more than 10,000 individuals representing 48 percent of all plants across the range. Fifteen other populations have over 1,000 plants. In contrast, 43 populations (37 percent) have less than 100 individuals and have Low abundance. Twenty-one of these populations (18 percent) have less than 20 individuals and are highly susceptible to extirpation based on historical trends of known extirpated populations.

For the purposes of this SSA, we determined that the breadth of adaptive capacity can be captured by distribution of populations of AHTF within two representative units (one with two sub-units). We chose these representative units based primarily on the genetic and ecological distinctiveness of the southern populations of AHTF when compared to those in the northern portion of the range. We consider the populations in the northern portion of the range to be the Great Lakes Snowbelt Unit with the Niagara Escarpment (Ontario and Michigan) and Onondaga Escarpment (New York) sub-units. We consider the populations in the southern portion of the range to be the Appalachian Karst Unit (Alabama and Tennessee). The AHTF has two distinct representative units that suggest there may be adaptive capacity across the species' range; however, the southern unit may have always been rare under current climatic conditions. While the Appalachian Karst Unit is distinct genetically and ecologically, we are uncertain what adaptive capacity may be found in the southern populations or what the overall impact the potential loss of this unit may have for the AHTF, generally.

Redundancy describes the ability of a species to withstand catastrophic events by maintaining multiple, resilient, populations well-distributed within the species' ecological settings and across the species' historical range. The Great Lakes Snowbelt unit contains nearly all of the populations and individual plants. As a whole, this representative unit has 142 populations and appears to have a high number of resilient, well-distributed, populations and was determined to have High redundancy as no

Table 0-1. Summary of Current Condition 3Rs by population for the AHTF.

Representative Unit (Subunit)	State(s)/Province	Redundancy	Resiliency					
			High	Medium	Low	Unknown	Extirpated	Historical
Great Lakes Snowbelt	ON, MI, NY	High	30	56	29	27	19	11
Niagara Escarpment	ON, MI	High	26	46	25	27	14	11
Onondaga Escarpment	NY	Low	4	10	4	0	5	0
Appalachian Karst	TN, AL	Very Low	0	1	1	0	3	0

Table 0-2. Summary of Current Condition 3Rs by number of individuals for the AHTF.

Representative Unit (Subunit)	State(s)/Province	Redundancy	Resiliency					
			High	Medium	Low	Unknown	Extirpated	Historical
Great Lakes Snowbelt	ON, MI, NY	High	107375	13431	851	?		
Niagara Escarpment	ON, MI	High	104092	12826	739	?		
Onondaga Escarpment	NY	Low	3283	605	112			
Appalachian Karst	TN, AL	Very Low	0	30	3			

catastrophic event is likely to simultaneously affect so many well-distributed populations. The Appalachian Karst representative unit is depauperate in the number of populations found within it. Only two extant populations remain, and based on the number of known records, the AHTF may never have been extensively distributed in the previous 100 years. As a catastrophic event could eliminate half to all of the populations in this representative unit, and the majority of all known populations are already extirpated, this representative unit was determined to have Very Low redundancy.

Based on the AHTF's life history and habitat needs, we identified the potential negative and positive influences and the contributing sources of those influences that are likely to affect the species' viability (Table 4-1; Figure 4-1). The primary stressors influencing AHTF population viability are logging, development, quarrying, invasive species, climate change impacts to snowpack and drought conditions, collection, recreation, and observer impacts. Logging, development, and quarrying have historically been the predominant issues with most known extirpations associated with these activities. Currently, only populations in New York are known to be heavily invaded by a widespread invasive species not associated with other disturbances, European swallowwort (*Vincetoxicum rossicum*). There are currently 59 protected populations (41 percent) of AHTF in the U.S. and Canada (Appendix A). An additional 14 populations in Ontario (10 percent) have partial protection. Of the protected populations, 47 (80 percent of all protected populations and 33 percent of all populations) are both protected and managed. Approximately, 62,000 plants (51 percent) are protected with approximately 98 percent of the protected plants also managed. Approximately, 34,500 plants (28 percent) are partially protected, as several large populations in Ontario are extensive and not contained within parcels owned by a single landowner. The number of protected populations, as well as additional regulatory protections in Ontario, limit but do not preclude most impacts from logging, development, and quarrying. Protected sites that are managed can also limit invasive species impacts.

We provide an analysis of the future viability of the AHTF under two potential scenarios over two timeframes to incorporate potential uncertainty with future predictions (Table 0-3). We examined two timeframes: 30 to 50 years and 50+ years. We chose these timeframes due to the perennial, long-lived nature of individuals of AHTF, and the availability of medium and long-term climate models, as climate is a significant factor affecting future population status. The available data allow us to reasonably predict the effects of stressors within the range of the AHTF during these timeframes. We selected climate change and invasive species as the most important factors to evaluate into the future. These factors were selected as our review has shown that these two factors are most likely to impact the majority of populations and individuals across the species' range. The climate change projections used in this SSA report are based on Representative Concentration Pathway (RCP) scenarios RCP 4.5 and RCP 8.5., and we assessed the likely impacts of European swallowwort and the Asian longhorn beetle (ALB) (*Anoplophora glabripennis*). The ALB was added to Scenario 2 as this species is predicted to spread primarily under RCP 8.5.

Table 0-3. Scenarios assessing future viability.

	Climate Model	Invasive Species
Scenario 1	RCP 4.5	Spread of European swallowwort
Scenario 2	RCP 8.5	Spread of European swallowwort and ALB

We found that our scenarios predict reductions in the number of AHTF populations and resiliency of populations across the species range with a strong eventual shift from High and Medium to Medium and Low condition populations except for Scenario 1 at 30 to 50 years (Figure 0-1). Scenario 1 generally predicts declines of mostly High and Medium condition populations in Ontario and New York, with the number of Extirpated populations increasing from 22 to 34 after 50+ years. Scenario 2 generally predicts more rapid declines of High and Medium ranked populations in Ontario and New York, largely in Ontario, with the number of Extirpated populations increasing from 22 to 43 after 50+ years. An unknown number of the predicted Low condition populations in both scenarios may also become Extirpated. The representation of the AHTF remains fairly consistent under both scenarios over time, although redundancy is expected to be lost in the southern portion of the range and notably reduced from High to Medium across the northern portion of the range under all scenarios after 50+ years (Figure 0-1). In general, impacts due to climate change are the most important, primarily in New York and Ontario. The invasion of the ALB in our second scenario had additional impact in addition to climate change, although this was ameliorated to some degree by changes in the distribution of European swallowwort and the eventual reduction in freeze/thaw damage under warming condition in RCP 8.5 in the late 21st century. We did not incorporate impacts due to logging, quarrying, recreation, or other stressors that are expected to occur primarily in Ontario, and our results are likely conservative regarding potential changes in condition and future extirpations with regard to these factors. Our future scenarios suggest that while Ontario currently contains the largest concentration of the AHTF, several of the stressors that are predicted to act on the species in the next 50+ years will be concentrated there, as climate shifts and invasive species spread to the area, and will result in proportionally large reductions in resilience and redundancy in the foreseeable future.

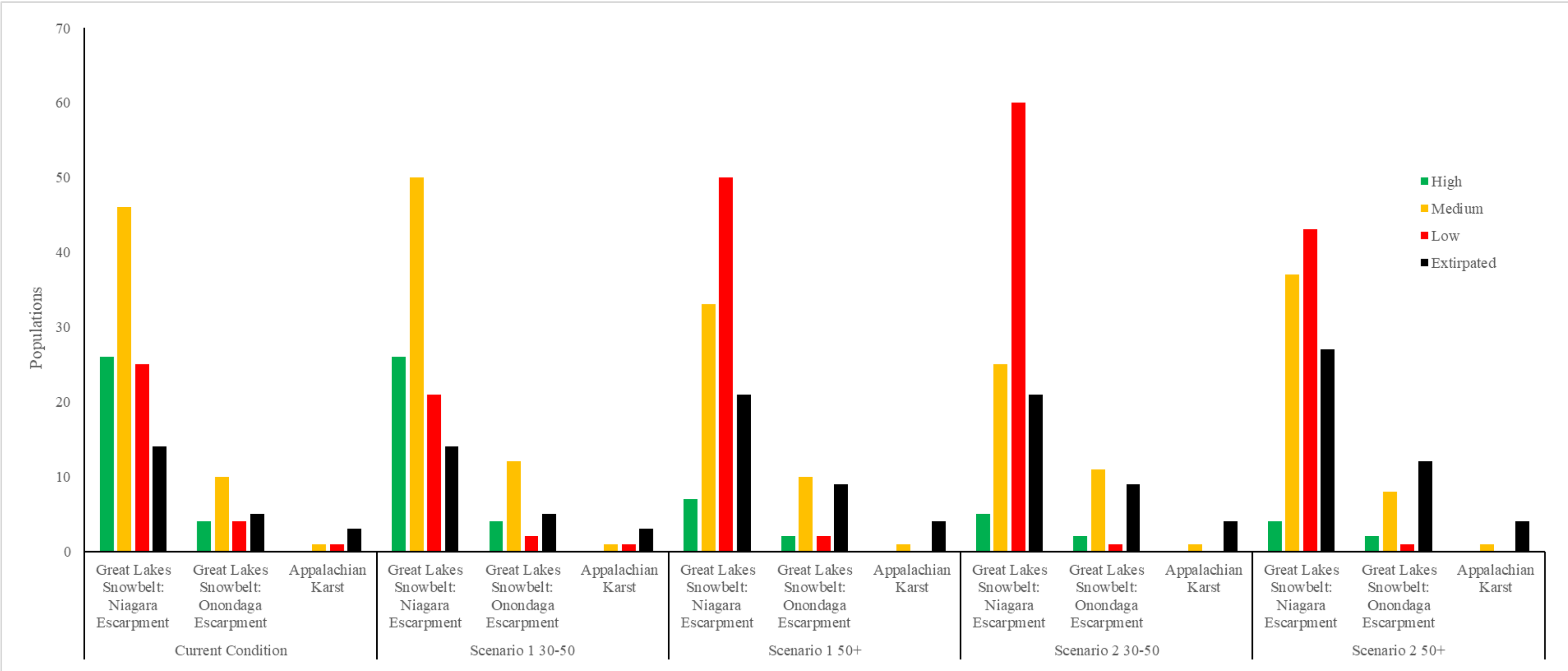

Figure 0-1. Summary of future condition of the AHTF by representative unit from two scenarios across two timeframes

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1 INTRODUCTION

1.1 Background

This report summarizes the results of a species status assessment (SSA) for the American hart's-tongue fern (AHTF), *Asplenium scolopendrium* var. *americanum* (=*Phyllitis scolopendrium* var. *americana*)). The U.S. Fish and Wildlife Service (Service) listed the AHTF as a threatened subspecies on August 14, 1989 (54 CFR 29726). The Recovery Plan for AHTF was issued on September 15, 1993 (USFWS 1993, entire). The results of this report will inform the next 5-year review for the species and help determine whether the AHTF is correctly classified as a threatened subspecies. As part of the 5-year review, the Service will also assess how well the Recovery Plan currently describes recovery for the species. We conducted a SSA to compile the best scientific and commercial data available regarding the species' biology and factors that influence the species' viability. Importantly, the SSA does not result in a decision by the Service under the Endangered Species Act (ESA). Any decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of any proposed changes in status will be announced in the Federal Register, with appropriate opportunities for public input.

1.2 Analytical Framework

The SSA report, the product of conducting a SSA, is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available, and to support all functions of the Endangered Species Program. As such, the SSA report provides a review of the best available information strictly related to the biological status of the AHTF and will be a living document upon which future delisting or reclassification decisions and other documents, such as future 5-year reviews and revisions to the Recovery Plan, would be based.

Using the SSA framework (Figure 1-1), we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (Smith et al. 2018, p. entire). For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in natural ecosystems within a biologically meaningful timeframe. For this SSA, we examined two timeframes: 30 to 50 years and 50+ years. We chose these timeframes due to the perennial, long-lived nature of individuals of AHTF, and the availability of medium and long-term climate models, as climate is a significant factor affecting future population status. The available data allow us to reasonably predict the effects of stressors within the range of the AHTF during these timeframes.

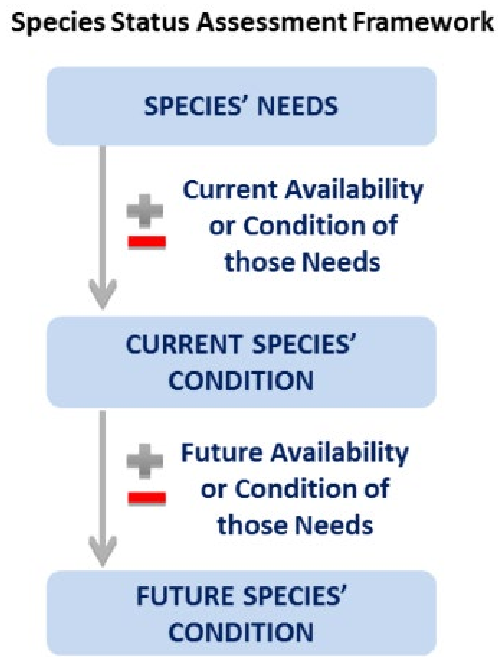


Figure 1-1. Species Status Assessment Framework

Resiliency, redundancy, and representation are defined as follows:

Resiliency means having sufficiently large populations for the species to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health, such as recruitment, senescence, and population size, if that information exists. For example, resilient populations are better able to withstand disturbances such as random fluctuations in population size (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of human activities.

Redundancy means having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations across the range of the species. Generally, the greater the number of populations a species has distributed over a larger landscape, the better it can withstand catastrophic events.

Representation is the ability of a species to adapt to near- and long-term changes in the environment; it is the evolutionary capacity or flexibility of a species. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics within the geographical range.

2 SPECIES INFORMATION

2.1 Taxonomy

The AHTF is a rare North American variety of the widespread hart's-tongue fern (*Asplenium scolopendrium*) that is common and abundant in Europe and Eurasia [European hart's-tongue fern (EHTF) (*Asplenium scolopendrium* var. *scolopendrium*)]. The AHTF was originally collected in North America near Syracuse, New York, in 1807 by Frederick Pursh (Maxon 1900, p. 31) and first described by Fernald (1935, p. 220) as *Phyllitis scolopendrium* var. *americana* from specimens from Ontario, Canada. Emmott (1964, p. 207) found that the AHTF and EHTF are segregated into tetraploid and diploid genomes, respectively. The variety was later grouped as a subspecies of plants from eastern Asia by Löve and Löve (1973, p. 205) based on interfertility of the plants and similarity of morphological characteristics. The genus *Phyllitis* was eventually subsumed within the larger genus *Asplenium* by Kartesz and Gandhi (1991, p. 196). The AHTF is classified within the spleenwort family of ferns (Aspleniaceae) and is considered a valid taxon by the scientific community (Wagner et al. 1993, p. 235).

The currently accepted classification is:

Class: Polypodiopsida
Order: Polypodiales
Family: Aspleniaceae
Genus: Asplenium
Species: *Asplenium scolopendrium*
Variety: *Asplenium scolopendrium* var. *americanum*

2.2 Species Description

The AHTF is an evergreen fern with life stages associated with a typical fern life cycle (see Section 2.3). Detailed botanical descriptions can be found in Lellinger (1985, pp. 228–229) and the Flora of North America (Wagner et al. 1993, p. 235). Briefly, the sporophyte has a crown of evergreen strap-shaped fronds with entire margins up to 35 to 40 centimeters (cm) (14 to 16 inches [in]) long and up to 2 to 4.5 cm (0.8 to 1.8 in) wide that taper to an acute tip and are auriculate at their base (Figure 2-1). The fronds arise from a vertical rhizome covered with cinnamon-colored scales (D. Fernando, SUNY-ESF, pers. com.). The brownish petiole is 3 to 12 cm (1.2 to 4.7 in) long and has cinnamon-colored scales. The sori are brown, linear in shape, and occur in two vertical columns on the underside of the frond. Spores from wild individuals in Mexico were roughly spherical and approximately 0.05 millimeters (mm) (0.002 in) in diameter (Arreguin-Sánchez and Aguirre-Claveran 1986, p. 402). Detailed description of laboratory-grown gametophyte morphology can be found in Testo and Watkins (2011, entire). The gametophyte is rarely observed but is pale to dark green, a single cell layer thick, and cordiform to reniform in shape and approximately 10 to 15 mm (0.4 to 0.6 in) in size with undulate edges and marginal hairs.

Figure 2-1. AHTF sporophyte depicting the entire margins, whorl of fronds, and auriculate bases. The largest leaves are approximately 30 cm (11.8 in) long.

2.3 Life History

The AHTF is a homosporous, leptosporangiate, evergreen fern that follows the general textbook life history of a fern (Figure 2-2). Briefly, all ferns alternate between haploid generations consisting of spores that grow into the life stage associated with sexual reproduction, the gametophyte, and diploid generations. The sperm and egg join on the gametophyte to form a diploid zygote that grows into the sporophyte life stage, which is familiar to most observers of ferns. Haploid spores are then produced and the life cycle continues (Figure 2-2). A heteromorphic alternation of generations is present in the AHTF, consisting of a tetraploid sporophyte generation (Britton 1953, p. 583) and gametophyte generation that are nutritionally independent of each other. Some evidence has indicated that ploidy level may vary within the hart's-tongue fern (D. Fernando, SUNY-ESF, per. com.). Britton (1953, p. 583) is commonly cited as the source of ploidy differences between the AHTF and the EHTF; however, only two individuals from Ontario, Canada, were utilized in this study (Testo and Watkins 2011, p. 400).

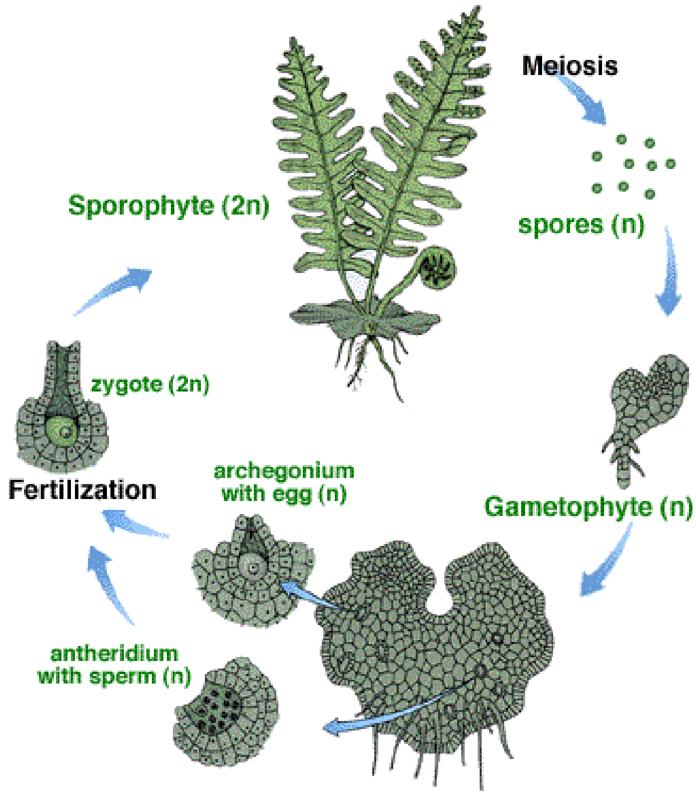


Figure 2-2. A generalized fern life cycle.

Spore dispersal mechanisms in the AHTF have not been well studied; however, it is widely accepted that wind is the primary spore dispersal mechanism for most terrestrial ferns. The AHTF habitats that are well-protected by cliff faces, sinkholes, and ravine walls may significantly limit the ability of AHTF spores to disperse long distances via wind (Cinquemani et al. 1988, pp. 38–42; Fernando et al. 2015, p. 33; Serviss 2017, p. 83). Additional spore dispersal mechanisms may be possible for AHTF, including short-distance dispersal after ingestion by slugs and snails (Boch et al. 2016, p. 17) and dispersal attached to various mammals (Barbé et al. 2016, p. 72; Sugita et al. 2013, p. 227). Spore dispersal for first season fronds generally begins as spores are released from the sori on the underside of the fronds in late summer; however, mature fronds from previous growing seasons may release spores opportunistically throughout the year (M. Serviss, New York State Office of Parks, Recreation and Historic Preservation [NYSOPRHP], pers. com.).

After the spores germinate, AHTF goes through a short threadlike growth phase (i.e., protonema) and subsequent gametophyte development is consistent with other members of the family Aspleniaceae (Nayar and Kaur 1971, pp. 348–350; Testo and Watkins 2011, pp. 401–402). Gametophytes for the species can be bisexual or unisexual (antheridia [male] or archegonia [female] only), (D. Fernando, SUNY-ESF, pers. comm. 2017), although Testo and Watkins (2011, p. 407) did not observe any bisexual gametophytes in their study and found fewer male gametopyhtes when compared to the EHTF. The species is known to reproduce primarily by sexual means; however, asexual reproduction of gametophytes from marginal fragmentation in laboratory conditions is also known to occur (Testo and Watkins 2011, p. 402).

Fertilization of most ferns may be achieved through three separate mechanisms: 1) intra-gametophytic selfing, 2) inter-gametophytic selfing, and 3) inter-gametophytic crossing (Weber-

Townsend 2017, pp. 1–2). These mechanisms, respectively, result in increasing levels of out-crossing, going from fertilization by gametes from: 1) one gametophyte from one sporophyte; 2) two gametophytes from one sporophyte; and 3) two gametophytes from two different sporophytes. Each mechanism requires a film of water for the sperm to reach and fertilize the egg; thus, moisture is necessary for successful sexual reproduction. The AHTF may be more or completely reliant on out-crossing than other ferns or than the EHTF, which may contribute to the species' rarity (Testo and Watkins 2011, p. 407). In a lab setting, AHTF gametophytes can reach maturity, indicated by the presence of antheridia and/or archegonia, within 60 days and may produce a small (<2 cm [<0.8 in]), persistent stage lacking the characteristics of larger sporophytes, referred to as a sporeling, within 90-120 days after sowing spores (Discenza 2012, p. 24; Serviss 2017, pp. 11–12) (Figure 2-3). However, gametophyte development, fertilization, and sporeling production in AHTF can take as long as 2 years or more (Pence 2015, p. 218).

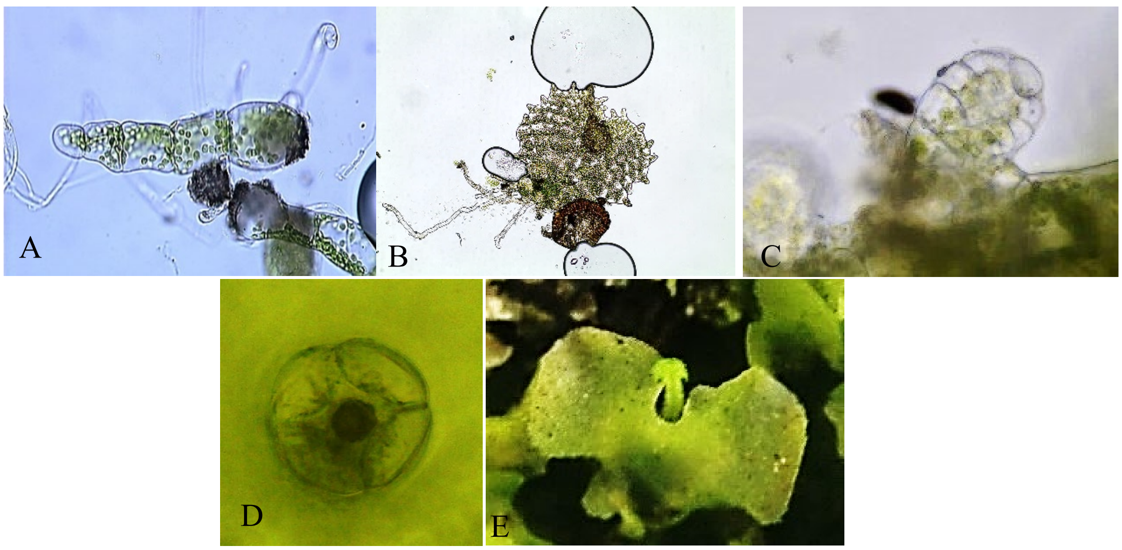
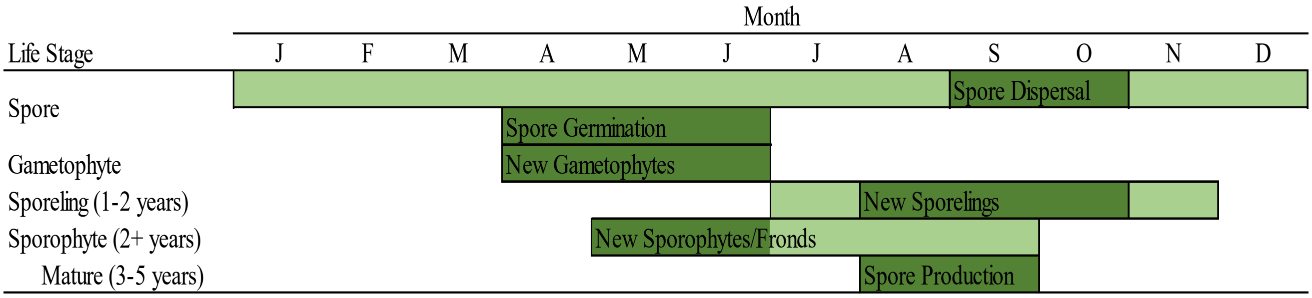


Figure 2-3. The stages of early gametophyte development of AHTF. A. Protonema at 14 days after sowing (400X). B. Early heart-shaped stage at 30 days after sowing (100X). C. Side view Archegonium at 60 days after sowing (400X). D. Top-down view Archegonium at 60 days after sowing (400X) (D. Fernando, SUNY-ESF, pers. com.). E. Mature gametophyte with young sporeling at 120 days after sowing (10X). Photos and caption by M. Serviss (see Serviss 2017, p. 12).

The phenology of AHTF reproduction and development in the wild has not been well studied; however, it is thought that spore germination and gametophyte development throughout the northern part of the species' range may begin in the spring after the snowpack has melted and prior to leaf out (Table 2-1). Gametophytes appear visible to the unaided eye by early to late June in New York (M. Serviss, NYSOPRHP, pers. obs.). Sporelings may develop shortly after gametophytes reach maturity in the early to mid-summer and sporeling production may continue throughout the growing season, possibly into late autumn prior to arrival of winter snowpack. It is possible that sporelings could be produced opportunistically throughout the growing season, as gametophytes are persistent and have been observed in the laboratory to be capable of asexual fragmentation to produce new gametophytes (Testo and Watkins 2011, p. 402). After growth and development into larger fronds, AHTF may exist in a non-reproductive, or immature, stage for 2 or more years. Sporophytes may reach maturity within 3-5 years, as indicated by the production of sori containing viable spores on the underside of the frond.

Table 2-1. Generalized chronology of the AHTF life history derived from observations in the northern portion of the range and in *ex situ* propagation efforts. The darkest green indicates the primary life stage periods, with medium green indicating extended periods known to occur. All life stages can be found throughout the year.



Seasonal timing of reproduction and development at the southern extent of the species' range is less certain, as the seasonal conditions within the limestone sinkhole habitats containing AHTF are likely different from the northern habitats. These sinkhole habitats occur in a warmer climate with little snowfall and are more buffered in a partially subterranean location. Temperature and light availability in the sinkholes are likely constraints on the development of AHTF in Tennessee and Alabama where winter snowfall is less prevalent than in the northern part of the range.

2.4 Range and Distribution

The AHTF is found in restricted areas of the eastern U.S. and Canada (Figure 2-4). Nearly all of the known AHTF populations and individuals are located in the Upper Peninsula of Michigan, south-central Ontario, and central New York, with disjunct southern populations in eastern Tennessee and northeastern Alabama. Other reported locations of the AHTF including New Brunswick, New Jersey, Maryland, and the Niagara Gorge, among others, (as discussed in Austen 2000, p. 6) are all considered erroneous plantings of EHTF, or small isolated plantings outside of the species native range. An additional population was planted on a green wall development in New York City in 2016 from individuals propagated at the State College of Environmental Science and Forestry (SUNY-ESF). These isolated out-plantings are not addressed further in this SSA because they are all either EHTF, are no longer extant, are of unknown status with no recent reports, or are in artificial environments.

The hart's-tongue fern is also known to occur in Mexico and Hispaniola (Wagner et al. 1993, p. 235). The Flora of North America (Wagner et al. 1993, p. 235) indicates that the collections from Oaxaca and Chiapas, Mexico are *A. scolopendrium* var. *lindenii* (Hooker) Fernald although Mickel and Smith (2004, p. 120) suggest the distinctions used to separate this variety from the AHTF may not be valid and additional research is needed regarding the taxonomic status of populations in southern Mexico and Hispaniola. The only Mexican populations determined by the Flora of North America (Wagner et al. 1993, p. 235) to be the AHTF are from Nuevo Leon, Mexico. The AHTF was most recently collected in 2004 from Parque Nacional Cumbres de Monterrey, west of Montemorelos, Nuevo Leon, from pine-oak forests in limestone ravines at 1,900 – 2,200 meters (m) (6,200 – 7,200 feet [ft]) (W. Testo, University of Florida, pers. comm.). While efforts are ongoing to gain more information about the AHTF in Nuevo Leon, there is currently no readily available information regarding the status of the species in Mexico beyond the information in the collection. We do not include any

Mexican populations in our analysis here due to a lack of specific information in this portion of the species' range.

Figure 2-4. Range of the AHTF in the eastern United States and Canada (figure from COSEWIC 2016, p. 10). Note that the species potential range in Mexico is not included in the figure.

2.5 Resource Needs

The AHTF is restricted to calcium-rich limestone substrates in cool, moist habitats under predominantly deciduous hardwood canopy (Figure 2-5). In New York, this species is restricted to steep limestone talus slopes on the Onondaga Escarpment within ravines and glacial plunge basins, most commonly on north to northeast aspects. In Michigan's Upper Peninsula, the AHTF occurs within areas with limestone pavement and in boulder fields under hardwood canopy, with sporophytes growing out of cracks in the rock or at the base of boulders. In Ontario, the AHTF is associated with a variety of habitat types, all associated with the Niagara Escarpment. These include talus slopes, boulders, and rocky woods (Soper 1954, p. 132). In the southern U.S., the AHTF is found in limestone cave mouths and sinkholes.

Figure 2-5. Habitats of AHTF in sinkholes of Alabama (upper left; photo from A. Cressler USGS); mid-slope basin boulder fields in New York (upper-right); boulder fields on flat terrain in Michigan (lower-left); and cracks in limestone pavement in Michigan (lower-right).

The AHTF occurs along the Silurian and Devonian age Niagara and Onondaga Escarpments in New York, Ontario, and Michigan. In the southeast, the AHTF is associated with Mississippian limestone exposed in sinkholes and caves. It is not known why the AHTF is so strongly limited to calcium-rich bedrock, but plants are always found in close association with limestone bedrock, wherever the AHTF occurs.

In the northern portion of the range, typical tree species in AHTF habitat are sugar maple (*Acer saccharum*) and American basswood (*Tilia americana*), with lesser amounts of yellow birch (*Betula alleghaniensis*), eastern hop-hornbeam (*Ostrya virginiana*), and bitternut hickory (*Carya cordiformis*). Eastern hemlock (*Tsuga canadensis*) is often present on slopes supporting AHTF, though the ferns typically do not occur directly underneath this or any other evergreen species (Cinquemani Kuehn and Leopold 1993, pp. 313–314; Futyma 1980, pp. 81–83). Commonly associated herbaceous species include white trillium (*Trillium grandiflorum*), round-lobed hepatica (*Anemone americana*), wild columbine (*Aquilegia canadensis*), wild ginger (*Asarum candense*), poison ivy (*Toxicodendron radicans*), herb-Robert (*Geranium robertanium*), and other species common to mesic northern hardwood sites. Two other Asplenium species can be found within basins in New York. Walking fern (*Asplenium rhizophyllum*) is often found growing on mossy boulders in close vicinity to AHTF, while maidenhair spleenwort (*Asplenium trichomanes*) is often found growing out of cracks in the limestone escarpment at the top of the slopes in drier microhabitats. Soil is limited on these slopes, generally occurring in shallow crevices and pockets, and is generally characterized by circumneutral pH and high concentrations of organic matter, calcium, and magnesium (Cinquemani Kuehn and Leopold 1993, pp. 313–314).

The specialized habitat in which the AHTF occurs is buffered against climatic extremes. In New York, AHTF habitats experience lower daily maximum temperatures and narrower daily temperature ranges than in immediately adjacent areas (Brumbelow 2014, pp. 40, 45–49). Brumbelow (2014, pp. 50–53, 56–57) also found that the AHTF is more likely to be found in microsites with less exposure to freezing temperatures and wide temperature fluctuations, suggesting a low tolerance for freezing or cold temperatures. While there are no specific freeze or cold tolerance data available for the AHTF, Lösch et al. (2007, p. 232) noted that EHTF had a frost tolerance between -5 and 5 °F (-21 and -15 °C). Northern populations of the AHTF occur within narrow heavy snow belts that overlap with the Niagara Escarpment. The apparent sensitivity of the AHTF to freezing and cold temperatures and its close association with snowbelts, suggest a dependence on consistent snow cover. It is possible that at a macro-scale, these two regional factors (i.e., limestones in the Niagara Escarpment and persistent snow cover in snow belts) determine the possible range of AHTF in the northern portion of the range (Figure 2-6). At one cave site at the southern extent of the species' range in Alabama, Garton (1995, pp. 1–6) recorded steady summer temperatures of 57 to 59° F (14 to 15° C) that were well below temperatures immediately outside the cave. The steep slopes of central New York's White Lake, a site that supported the AHTF before quarry operations eliminated this species here, were found to have considerably lower temperature and higher humidity than the surrounding area (Petry 1918, pp. 205–207). Gates (1962, p. entire) studied differences in temperatures between locations where AHTF was present or absent within one New York site, noting that where the AHTF occurred, temperatures fluctuated less on north to northeast facing slopes, and that steeper slopes could contribute to lower temperatures.

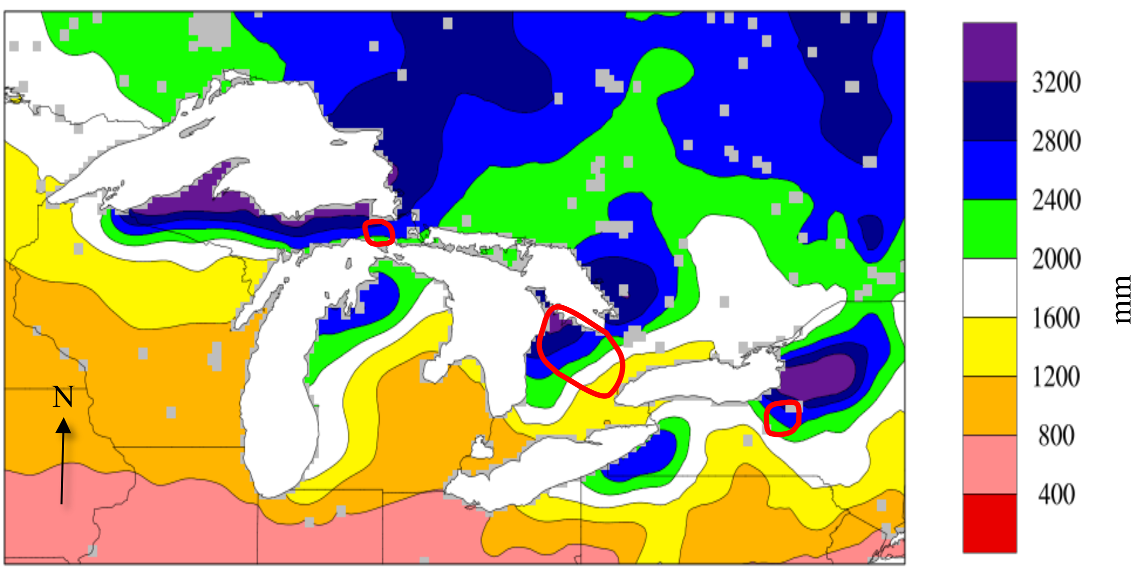


Figure 2-6. Distribution of AHTF populations in the Great Lakes in relation to climatological annual (i.e., winter) snowfall (mm). Data were interpolated from the Global Historical Climate Network – Daily dataset from 1930-2018. Red outlines indicate the three concentrations of AHTF. Data and figure from M. Notaro, Nelson Institute Center for Climatic Research.

The relationship between habitat characteristics and the occurrence of different life stages of the AHTF in all populations in New York State was investigated by Cinquemani Kuehn and Leopold (1993, pp. 310–318). They found that percent cover of all combined sporophyte life stages of the AHTF (sporeling, immature, and mature) was negatively correlated with percent herb cover and that few AHTF of any life stage occurred where herb cover exceeded 50 to 75 percent. When the life history stages were investigated independently, sporelings were positively correlated with herb cover, with the largest proportion occurring in 26 to 50 percent herb cover, while mature sporophytes were negatively correlated with herb and bryophyte cover. Mature and immature sporophyte cover was positively correlated with bare or humus-filled rock crevices, while sporelings were positively correlated with bryophyte-covered rock crevices and surfaces. A majority of the AHTF of all life history stages in New York occurred in rock crevices, with very few individuals growing directly on rock surfaces. However, AHTF typically grow directly on the lower portions of moss-covered boulders in Michigan (Futuyma 1980, pp. 82-86) and may occur more frequently on the tops of rocks in Ontario, Canada (Ransier 1913, p. 37). Sporelings were positively correlated with greater light intensity than mature and immature AHTF, often occurring in and around the edges of gaps in the tree canopy. In general, it has been shown that the AHTF occurs in areas of low herbaceous cover, in shallow soils in close association with bryophytes and limestone bedrock, and in relatively low light conditions.

Testo and Watkins (2011, pp. 2267–2269) evaluated the response of the gametophyte to different aspects of temperature, desiccation, and competition and found that the gametophyte life stage is particularly sensitive to higher temperatures and had lower levels of drought tolerance than other fern species occurring in similar habitats. The AHTF gametophytes have been found to be 86 percent smaller when grown at 77 °F (25 °C) compared to 68 °F (20 °C), a considerably larger reduction than other fern species occurring in similar habitats (Testo and Watkins 2011, p. 2267). Additionally, the AHTF had the only significant drop in spore germination when grown at these two temperatures down to approximately 1.5 percent from 9 percent (Testo and Watkins 2011, p. 2267).

Table 2-2 Summary of AHTF resource needs by life stage.

Resource	Life Stage			
	Spore	Gametophyte	Sporeling	Sporophyte
Moisture (cool/moist microclimate, well-drained)	HN	HNR	HN	HN
Light (deciduous canopy, low herbaceous cover)	HN	HN	HN	HN
Substrate (crevices, soil depth, High Mg limestone bedrock)	HN	HN	HN	HN
Wind	R			R
Freeze/thaw protection (winter snowpack, southern climate)		H	H	H
Bryophytes	H	H	H	

H=habitat; N=Nutrition; R=Reproduction

2.5.1 Individual Needs

We evaluate the individual needs of the AHTF in terms of the resource needs (Section 2.5) that are necessary to complete each stage of the life cycle (Section 2.3), including spore, gametophyte, sporeling, and sporophyte (Table 2-2). The life history of the AHTF is closely tied to the calcium-rich bedrock and shaded moist, cool microclimates for the habitat and nutrition of all life stages. The EHTF has been shown to maximize photosynthesis during cooler spring and fall periods when temperatures are lower, moisture is higher, and shortly before and after leaf production in the canopy (Lösch et al. 2007, p. 234), and the AHTF likely also follows this pattern. Reproduction occurs during gamete exchange on the gametophyte, which requires moisture in the form of a film of water, and during spore dispersal, which involves wind dispersal of spores from the sporophyte to suitable habitat. The AHTF occurs in cool microclimates; however, it appears to be vulnerable to damage by freeze-thaw cycles as freeze-thaw can damage not only leaf tissue of the EHTF (which is generally more robust than AHTF) (Bremer and Jongejans 2009, p. 220), particularly for sporelings (Kelsall et al. 2004, p. 166), but also dislodge individuals due to frost heaving (Brumbelow 2014, pp. 56–57; Cinquemani Kuehn and Leopold 1992, p. 75). Other potential impacts to rhizomes and roots are also possible (D. Fernando, SUNY-ESF, pers. com.). Conversely, Testo and Watkins (2013, p. 2264) found higher germination rates for AHTF in laboratory conditions after exposure to prolonged freezing, so spore life stages may be less susceptible to frost damage. Bryophytes have been noted to be closely associated with earlier life stages; however, Cinquemani Kuehn and Leopold (1993, p. 315) found that adult sporophytes were less commonly associated with bryophytes.

2.6 *Population Needs*

In order to assess the viability of a species, the needs of individuals are only one aspect. This Section and Section 2.7 examine the larger-scale population and species-level needs of the AHTF. For the purpose of this assessment, we define viability as the ability of the species to sustain populations in the wild over time. Using the SSA framework, we describe the current species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (the 3Rs).

We define a population of AHTF as any localized collection of individuals separated from other individuals by at least 65 ft (20 m). This definition of a population is not in agreement with the general protocol for defining populations of rare species as all individuals within a 0.6 mile (mi) (1kilometer [km]) radius (NatureServe 2002, p. 26); however, this definition is based on the best available genetic information and our analysis of the potential for gene flow and dispersal for AHTF (Section 2.6.2). We acknowledge that the Environmental Occurrences (EOs) recorded by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (2016, entire) utilized a 0.6 mi (1 km) separation distance for populations, and our population estimates in Ontario are likely conservative based on our definition presented in this SSA. Currently, there is no way to reconcile this difference as some populations in Ontario are small and isolated or large and continuous, and would still match our definition; however, for some populations that are large and patchy, there may be an unknown number of additional populations based on our definition. While our current population estimates are likely conservative due to this discrepancy, our future scenarios (Section 5) may be less conservative, as a loss of a population in Ontario may actually represent more than one population based on our definition. In this SSA, when we refer to a population, we refer to our definition as presented above for populations in the U.S. and to a population as delimited by NatureServe when referring to populations in Ontario.

We evaluate the population needs of the AHTF in terms of what is required for self-sustaining populations. The measure of resiliency is based on a population's ability to withstand or recover from environmental or demographic stochastic events, such as disturbances that remove or degrade the canopy or severe climatic conditions associated with drought or winter freeze-thaw processes. We evaluate resiliency in terms of resources and/or the circumstances that are necessary to maintain population abundance, distribution, population growth rates, and reproduction. In addition to the habitat needs discussed in Section 2.5.1, AHTF populations are anticipated to be most resilient when they are large in size and have neutral or positive trends in abundance.

2.6.1 Population Size and Trends

Demographic data for the AHTF populations in New York are available from surveys that have been conducted roughly every 5 years since 1916 (Brumbelow 2014, pp. 12–36; Cinquemani et al. 1988, pp. 37–43; Faust 1960, pp. 55–62). Populations on National Forest land have been monitored regularly since the early 2000s; however, these data are relatively short-term. Most populations across the rest of the species' range have not had any regular surveys. As the dataset from New York is the most robust and continuous, we utilized these data for our evaluation of AHTF population sizes. We utilized an expert team to review the available long-term survey data and determined at which sizes populations are considered large and stable versus those that are susceptible to declines and potential extirpation. We utilized the most recent survey as our measure of abundance for all populations, as the majority of all populations of the AHTF do not have extensive survey data to determine any previous sizes or trend.

Populations of AHTF may oscillate by 100-200 individuals between surveys, likely due to a variety of factors, including environmental variability (e.g., drought, freeze/thaw exposure, canopy openings) and unquantified sampling errors that may occur (Brumbelow 2014, pp. 26–28). There is no evidence to suggest that populations that have been consistently small will rapidly increase in size, as this ability to cycle has only been observed in larger populations.
The presence of multiple persistent life stages of AHTF (Table 2-1) within a population likely leads to increased resiliency for AHTF. While counts of sporophytes may decline in some years, our review of the life cycle of the AHTF (Section 2.3) indicates that populations should be bolstered in subsequent years through resprouting from persistent rhizomes, recruitment of sporelings, sexual reproduction of gametophytes, and germination from persistent spore banks. Therefore, we consider populations of the AHTF to be more resilient when all life stages are represented.

We have determined that AHTF populations with a most recent survey of **400** individuals or more are likely resilient to the natural variability and stochastic events the species experiences. We have included trend data in our analysis, when available, in order to include information, when available, regarding long-term increases or decreases in population size. Populations of this size can recover from periodic fluctuations of hundreds of individuals and have been rarely noted to consistently decline lacking clear external stressors. Populations numbering between **100 and 400** individuals are less resilient, as fluctuations of hundreds of individuals may reduce the populations to small numbers from which recovery has been observed to be slow or unlikely. Populations **below 100** individuals, while they may persist over time, have little capacity to recover from population fluctuations due to environmental stochasticity and were considered by the expert team those populations most likely to decline to a point where extirpation would be likely.

2.6.2 Dispersal and Population Connectivity

Considerable effort has been placed on determining the genetic relationship and genetic exchange among populations of the AHTF. Discenza (2012, p. 47) utilized Inter-Simple Sequence Repeat (ISSR) molecular markers to evaluate the genetics of eight AHTF populations in New York and found that the diversity of the AHTF was generally low, although not lower than other common ferns in the genus *Asplenium*, and that the diversity among populations was largely driven by one unusually diverse population. This unusually diverse population is currently a topic for future research regarding its genetic origins. Removal of this population from Discenza (2012, entire) would result in the genetic diversity of the AHTF being very low.

The AHTF was observed to out-breed in the laboratory with individuals from other populations, suggesting that low genetic diversity in AHTF does not arise due to biological barriers to out-crossing (Discenza 2012, p. 48). However, this study found that nearby populations of AHTF are no more similar to each other than more distant ones, suggesting chance dispersal events of unique individuals and little genetic exchange (Discenza 2012, p. 34). Fernando et al. (2015, pp. 32–33) expanded this study to include three additional populations from Michigan, and found that, while populations differed across regions, a lack of genetic clustering or shared alleles within regions indicates that genetic exchange is low. They concluded that population genetic structure of the AHTF is consistent with rare long-distance spore dispersal events and within population inbreeding. Weber-Townsend

(2017, p. 21) also expanded this effort to include ISSR and microsatellite data with two additional populations from Michigan, three populations from Ontario, Canada, the population from Tennessee, and the population from Alabama. These populations were analyzed against an outgroup of commercially available plants, presumably EHTF. Weber-Townsend (2017, pp. 74–75) found that, regardless of structuring across regions, gene flow within regions was low, and that individual populations merited protection as individual management units.

The AHTF is likely limited by dispersal and establishment processes, as apparently abundant available habitat occurs along the Niagara Escarpment, and in a variety of other cave and sinkhole habitats in Tennessee and Alabama. Wild and Gagnon (2005, pp. 193–194) noted that other rare calcicolous ferns in Canada were apparently present near abundant habitat, but were limited by dispersal and establishment processes. The basin slopes, forested habitats, and boulder fields known to harbor the AHTF are also areas prone to low wind velocities. Serviss (2017, p. 83) noted that wind speeds at three populations in New York 1 m (3.3 ft) above the forest floor were always less than 0.38 m/s (1.25 ft/s), nearly nine times less than the wind speeds recorded at a nearby weather station. Raynor et al. (1976, pp. 478–479) conducted spore release trials on similar sized spores to those of the AHTF in forest environments at wind speeds of 0.4 m/s (1.31 ft/s) and found that nearly all spores settled to the ground within 20 m (65 ft) of the release point. This study released spores at a height of 1.75 m (5.74 ft), considerably higher than the AHTF is known to grow. We expect that AHTF disperses the vast majority of its spores within close proximity to the sporophyte, with long-distance dispersal exceedingly rare due to the low wind speeds found in its habitats, low point of release, and relatively larger spore size compared to other fern species. Despite decades of searches, there is no evidence to suggest that new populations of AHTF have originated from longer-distance dispersal events in that time.

While genetic exchange among populations of the AHTF may be beneficial, we do not believe it is necessary for the persistence of resilient populations of the AHTF. This is based on our assessment of the limited dispersal capability, and consequently limited genetic exchange, for populations of the AHTF, that appear to be healthy and remain stable over time. Therefore, we do not consider the proximity or exchange among populations of the AHTF as a component of resiliency within the SSA.

2.7 Species Needs

The AHTF needs multiple resilient populations distributed throughout its range to provide for redundancy and representation. The more populations, and the wider the distribution of those populations, the more redundancy the species will have. Redundancy reduces the risk that a species as a whole would be negatively impacted if an area of the species' range is negatively affected by a catastrophic natural or anthropogenic event at a given point in time and increases the probability of maintaining natural gene flow and ecological processes. Species that are well-distributed across their historical range are less susceptible to the risk of extinction following a catastrophic event than species confined to smaller areas of their range.

Representation is the ability of the species to adapt to physical (e.g., climate conditions, habitat conditions, or structure across large areas) and biological (e.g., novel diseases, pathogens, predators) changes in its environment presently and into the future; it is the evolutionary capacity or flexibility of the species. Representation is the range of variation found in a species, and this variation, called adaptive diversity, is the source of species' adaptive capabilities. Representation for the AHTF can be described in terms of variability among environmental settings and genetic diversity and can be measured by the number of resilient populations in each representative unit (see Section 3.3.2).

2.8 Synopsis

Viability is the ability to sustain populations over time. To do this, AHTF needs a sufficient number and distribution of viable populations to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and changes in its environment (representation) (Table 2-3).

Table 2-3. Ecological requirements for species-level viability.

3 Rs	Requisites of long-term viability	Description
Resiliency (able to withstand stochastic events)	Healthy populations	Populations with 1) sufficiently large size; 2) presence of all life stages (reproduction); and 3) suitable habitat
Representation (to maintain adaptive diversity of the species)	Maintain adaptive diversity of the species	Healthy populations distributed across areas of unique adaptive diversity (i.e., ecoregions)
Redundancy (to withstand catastrophic events)	Sufficient distribution of healthy populations	Sufficient distribution to guard against catastrophic events wiping out portions of the species adaptive diversity, i.e., to reduce covariance among populations

3 CURRENT CONDITION

In this chapter, we provide a review of the trends in the populations of the AHTF and provide our analysis of the current 3Rs of the species.

3.1 Reported Populations Since Listing[1]

When the AHTF was listed under the ESA in 1989, there were 16 extant populations known in the U.S., and in Ontario, Canada, it was considered locally abundant with no described records of individual populations (54 CFR 29726). In 1993, the Recovery Plan recognized 21 extant populations, due to the discovery of two additional populations in Michigan and the reporting of

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[1] Note that prior to this SSA, the Service did not have a precise definition for what constitutes a population of the AHTF. While all reports from Canada have been consistent in using the NatureServe 0.6 mi (1 km) distance cut-off, in the U.S., previous literature accounts have defined a population more informally and state natural heritage programs have eventually begun using the NatureServe definition since its publication in 2002. As a result, the number and definitions of populations have shifted or have consisted of an amalgamation of definitions over time (as they do in this SSA due to the data available from Canada). In this section, we report the numbers of populations, as reported in each document. Elsewhere in this SSA, we utilize our definition for populations in the U.S. and utilize the population numbers as provided in Canadian reports, which are based on NatureServe criteria.

additional populations in New York that had been known prior to the publication of the original listing rule. The Recovery Plan lacked detailed information regarding populations in Ontario (USFWS 1993, pp. 3–6). Both the original listing rule and the Recovery Plan reported the total U.S. population at a few thousand plants, primarily in New York, with one population in Michigan containing over 500 plants and two others having several hundred plants each (USFWS 1993, pp. 4–5).

In 2000, the COSEWIC provided the first quantitative assessment of AHTF in Ontario. The COSEWIC recognized a minimum of 74 extant populations across 101 EOs with several populations estimated in the 1,000s to 10,000s of plants (Austen 2000, pp. 12–13). Austen (2000, pp. 27–28) found that Ontario contained at least 73 percent of the known populations of AHTF, of which some are much larger and more extensive than those found in the U.S. Austen (2000, pp. 14–19) also reported 29 extant populations in the U.S for a total of 103 extant populations in the U.S. and Canada. The number of populations in the U.S. increased from the 21 extant populations noted in the Recovery Plan due in part to the discovery of 4 additional populations in Michigan. The remainder of the increase was due to improved data gathering based on Kelsall (2004, p. 164).

In 2012, the Service completed a 5-Year Review for the AHTF that described 30 extant populations in the U.S. Since 2000, 2 additional populations had been discovered in Michigan and a population on Service Refuge lands in Alabama was determined to be extirpated (USFWS 2012, pp. 7–14). In 2016, COSEWIC completed a second status assessment for the AHTF in Canada that recognized 109 extant populations across 132 EOs with two populations extirpated since the previous COSEWIC report in 2000 (COSEWIC 2016, pp. 22–24). The total Canadian population was estimated at 110,000 individuals and represented 80 percent of the populations and 94 percent of the individuals in the U.S. and Canada.

In summary, since the AHTF was originally listed, the number of known extant populations of AHTF increased in published reports, prior to this SSA, from 16 populations in the U.S. consisting of a few thousand individuals to 139 populations in the U.S. and Canada consisting of a little over a hundred thousand individuals. The known range of the AHTF did not change during that time.

3.2 Methods

3.2.1 Demographic Parameters and Assumptions

This analysis is conducted at the population level as defined in Section 2.6. Within populations, survey data have historically been recorded for each of three life stages: adult (presence of spore-producing structures), immature, and sporeling. Survey data have not been collected regarding the abundance of gametophytes or spores. The abundance of sporelings is known to be highly variable, and due to their small size and difficulty in identification, the inclusion of this life stage in survey efforts has been intermittent and more prone to error. As the adult and immature life stages are generally more persistent, and the data are more reliable, the combined abundance of adult and immature individuals is utilized in this SSA to evaluate long-term population sizes and trends and the resilience of AHTF populations.

The AHTF has an extensive survey history in New York, spanning over 100 years (see Section 2.6), and the populations in Tennessee and Alabama have been irregularly surveyed since their discoveries in 1879 and 1979, respectively. New York populations on private lands have more variable lengths between surveys, although most still have had multiple surveys over time. The populations in Michigan were discovered more recently, some within the last 10 years. The majority of the populations in Michigan are located on U.S. Forest Service (USFS) lands and are regularly surveyed every 2-5 years, while the two largest populations are located on private preserves and were only quantitatively surveyed in the last 5 years. In Ontario, some locations have been visited regularly over time; however, few quantitative surveys have been made, even at the most well-known sites. Many locations in Ontario have only been visited once and not for many years.

In this SSA, we have used the best available scientific and commercial information to inform our analysis of the resilience of AHTF populations. For most populations in the U.S. and a few populations in Ontario where periodic survey data are available, we have used these data to evaluate population trends for our rankings. The AHTF populations can be highly variable, and trends developed from shorter-term surveys with less than 10 years of data may not be representative of long-term trends in the population (see Section 2.6). Additionally, some surveys were of variable effort and quality or included transplanted individuals that did not survive over time (Faust 1960, p. 59). We determined trend based on expert review (see Acknowledgements) of the available data rather than a quantitative fit of counts over time. Where periodic data were absent or too short-term to make reasonable inferences regarding trend, we utilized only the most recent count data for the population to assess resilience. Trend data were included if changes in the population could be observed in the short-term due to changes in the stressors at a population (i.e., logging of a population from one survey to the next). Population declines due to habitat degradation may be slow to recover or lead to additional declines. Incorporation of short-term (less than 10 years) information into the Trend rank, in these situations, informs our understanding of long-term trends.

3.2.2 Analysis

The Service assessed population resilience for extant populations of the AHTF (Section 2.6) through a qualitative assessment of demographic data for AHTF and likely impacts of the habitat factors identified as resource needs for the species (Section 2.5.1, Table 3-2). A summary of the inputs and calculations can be found in Figure 3-1. The demographic data evaluated were based on: 1) the most recent survey counts of adult and immature sporophytes at each population (Abundance); 2) trend data from any long-term monitoring (i.e., greater than 10 years; see Section 2.6) or from declines associated with habitat degradation (Trend); and 3) evidence of successful reproduction and direct impacts to individuals (Reproduction). The resource needs considered included Moisture, Substrate, Light, and Freeze/Thaw Buffering as described in Section 2.5.1. The impact of invasive species on Substrate and Light availability were included in those metrics (see Section 4.4).

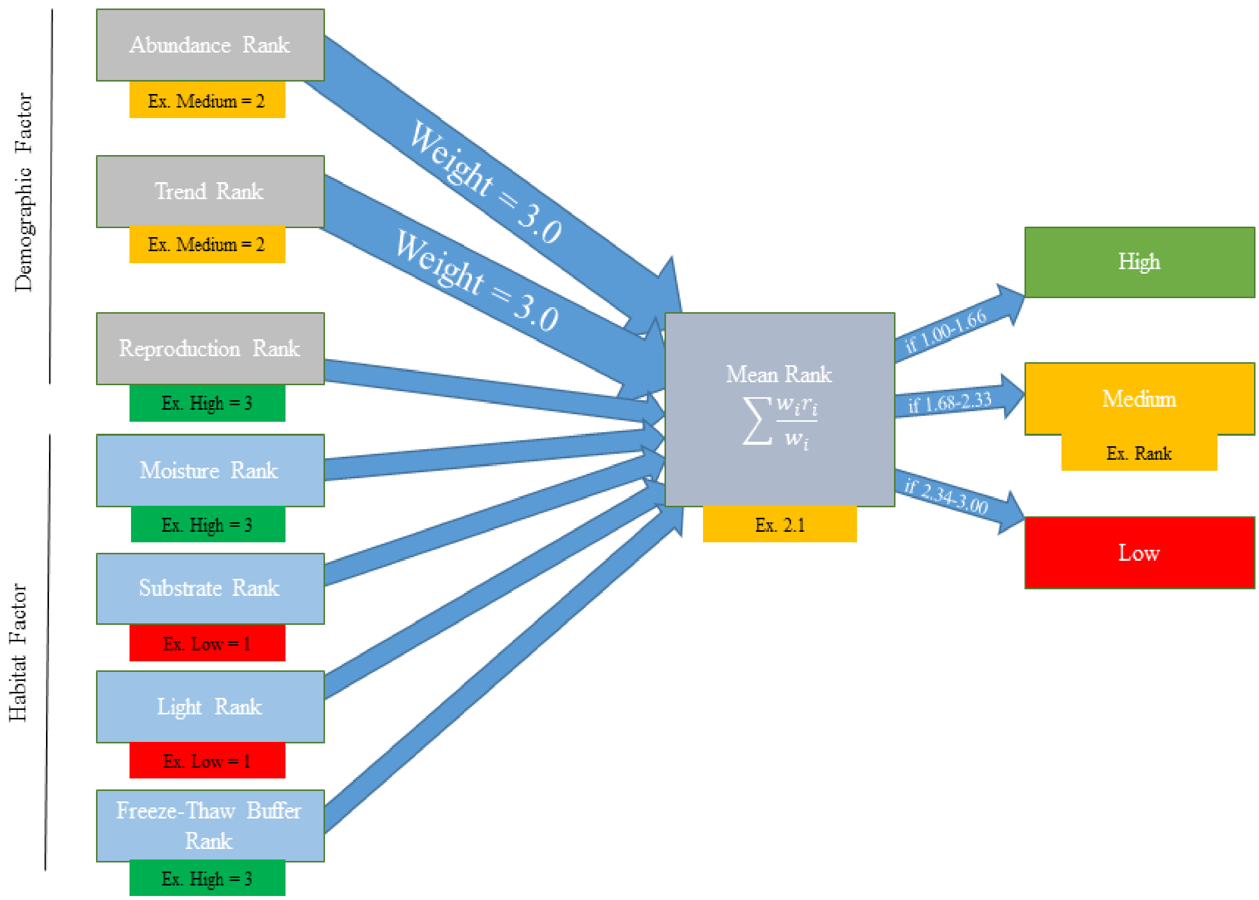


Figure 3-1. Diagram of Rank calculation with example (Ex.). Abundance and Trend Ranks (r) were given a weight (w) of 3.0 (thicker arrows). All other weights were 1.0 (thinner arrows). Additional detail regarding the factors included in the analysis and the ranking metrics can be found in Section 2.5.1, Table 3-2, and the text below.

Some populations in Ontario did not have any available survey data. For those populations lacking detailed location data and classified by COSEWIC as historical, we classified these as "Historical." These populations have not been confirmed as extant, or extirpated, and have been presented in the SSA but not analyzed for current condition lacking further survey effort to inform their condition. For those populations in Ontario that have been considered extant by COSEWIC, but lack survey data, these populations were classified as "Unknown."

Our qualitative assessment of population resilience involved first ranking each of the seven demographic and habitat factors as "Low", "Medium", or "High" based on specific criteria described in Table 3-2. A core team of species experts (See Acknowledgements) reviewed each population for which they had expertise against these criteria and an overall resilience Rank of "Low", "Medium", or "High" was assigned for each population. Each ranking was assigned a value of "Low" = 1, "Medium" = 2, and "High" = 3 and a weighted mean resilience across all factors was calculated. In order to balance the importance of low population numbers and changes in trends over time with the number of other factors considered in the analysis, Abundance and Trend were each given a weight of 3.0 in the calculation of mean resilience. Generally, only Abundance data were available for ranking, and this weighting allowed Abundance to represent approximately 40 percent of the calculation with no Trend data available. When usable Trend data were available, Abundance + Trend determined approximately 85 percent of the calculation, which is justified as these data are fundamental indicators of current condition. Additionally, this weighting scheme prevented one or two highly ranked resource factors from swamping "Low" demographic conditions when data were more limited. As widespread declines associated with freeze/thaw damage are not known to currently occur, all populations were assigned a "High" Rank for freeze/thaw buffer for current condition. The final weighted mean values ranged from 1-3, and the final population Rank was classified at "Low" = [1.00-1.66], "Medium" = [1.67 - 2.33], and "High" – [2.34 - 3.00] to provide an even distribution of values among ranks (Figure 3-1).

Our team of species experts was well-suited to evaluate the U.S. populations, and our method and final ranks were calibrated against our knowledge of the current condition of these populations. As we do not expect different factors to affect the current condition of populations in Ontario, our calculated ranks should be appropriate across this portion of the species range as well. At populations where recent information was available, the final ranks were supported by the expert team. Where information was lacking, our calculated rankings were largely informed by the most recent Abundance data.

3.2.3 Uncertainty

In this SSA, we present uncertainty in order to assess confidence in our rankings of population resiliency. In general, populations in the U.S. have been well-documented and recently surveyed, as a component of this SSA and for other ongoing efforts. In contrast, less information is generally available about the habitats and stressors that may be present at each of the Ontario populations, which have been less recently surveyed. We recorded the most recent dates for surveys (quantitative, accurate count data) and visit (qualitative, no accurate count data) dates for each population (Appendix A). For populations with the most recent quantitative survey no older than 10 years, we considered these Abundance data recent and of "Low" uncertainty. For populations with an older quantitative survey date, but a most recent qualitative survey documenting presence of the AHTF no older than 10 years, we considered these data of "Medium" uncertainty. If a population did not have a quantitative or qualitative survey in the last 10 years, we considered these data as having "High" uncertainty (Table 3-1).

Table 3-1. Summary of survey uncertainty classification.

	Uncertainty		
Type of Survey	Low	Medium	High
Quantitative <10 years	X		
Quantitative >10 years & Qualitative <10 years		X	
Quantitative >10 years & Qualitative >10 years			X

In some cases, descriptive estimates of abundance were provided in the most recent survey. In cases where terms such as "abundant" or "common" were used, we gave these populations a set Abundance of 100 individuals and considered these data of "Medium" uncertainty, unless the survey data were greater than 10 years old, in which case these data were still considered as "High" uncertainty. We set these populations at 100 individuals as a conservative estimate of Abundance, as these populations were then considered of "Medium" rank for our analysis. Many population estimates from Ontario included a range of numbers of individuals (e.g., "100-200" or ">50"). In these cases, we used the lowest number as the abundance. Therefore, our estimate of recent abundance across populations, primarily in Ontario, is potentially conservative.

Data for each of the 7 ranking factors in the analysis were not always available for every population. In order to document our uncertainty with our rankings of resilience, we calculated the percentage of missing factors and ranked uncertainty as "Low" = less than 25 percent of missing factors, "Medium" = less than 50 percent of missing factors, and "High" = greater than or equal to 50% of missing factors. Generally, populations in the U.S. have been well-documented and could be readily assessed. In Ontario, only 36 percent of the populations have recent survey information, and few of the populations have been assessed for the resource needs analyzed in this SSA. Therefore, resiliency rankings for populations in Canada are more uncertain based on the methods utilized in this SSA.

Table 3-2. Criteria for qualitative rankings of demographic data and habitat factors utilized in assessing the resiliance of AHTF populations.

Resilience	Abundance	Trend	Reproduction	Moisture Condition	Substrate Condition	Light Condition	Freeze/thaw buffer condition
High	The most recent population estimate is greater than or equal to 400 individuals.	Increasing	All life stages present in similar abundance and evidence of spore production. No life stages are exposed to direct impacts.	Moisture conditions are adequate to support the growth and reproduction of all life stages. Bryophytes are common.	Substrates are composed of dolomitic limestone with adequate soil rooting depth. No historically present substrate has been lost. Soil competing invasives are not present.	Light conditions are consistent with those found under a closed canopy deciduous forest with an understory cover of less than 25%. Canopy removing and understory invasives are not present.	The population has an adequate freeze/thaw buffering capacity through either snowpack coverage through the winter or geothermal buffering.
Medium	The most recent population estimate is between 100-400 individuals.	Stable	All life stages present although one or more life stages are known to be reduced in prevalence and evidence of spore production. Some life stages are exposed to direct impacts infrequently.	Moisture conditions are marginal compared to a high condition site. Bryophytes are infrequent or reduced in cover.	Substrates are composed of dolomitic limestone with marginal soil rooting depth. No more than 25% of any historically present substrate has been lost. Soil competing invasives are not present, present but managed, or nearby and likely to invade habitat.	Light conditions are generally those of a closed canopy deciduous forest; however, loss of canopy adjacent to the population has occurred. Understory cover is less than 25%. Canopy removing invasives are not present. Understory competetor invasives are not present, present but managed, or nearby and likely to invade habitat.	The population has marginal freeze/thaw buffering capacity due to periodic losses in snow pack during critical freezing periods.
Low	The most recent populations estimate is less than or equal to 100 individuals.	Declining	All life stages not present and/or lack of spore production. Some life stages are exposed to direct impacts regularly.	Moisture conditions are inadequate to support the growth and reproduction of all life stages. Bryophytes are not readily observed.	Substrates are generally lacking dolomitic limestone or adequate soil rooting depth. Greater than 25% of any historically present substrate has been lost. Soil competing invasives are present and not managed.	Light conditions are not consistent with a closed canopy deciduous forest. Loss of the canopy has occurred. Understory cover is greater than 25%. Canopy removing invasives may be present. Understory invasives are present and not managed.	The population has low freeze/thaw buffering capacity due to limited development of snow pack duing critical freezing periods.

An overall uncertainty was determined for each population based on the uncertainty in the available Abundance data and ranking factors for the analysis as presented in Table 3-3. Generally, overall uncertainty was determined by the uncertainty in the Abundance data. In cases where there was "High" uncertainty in the ranking factors, we increased our overall estimate of uncertainty.

Table 3-3. Determination of overall uncertainty for current condition based on the combined uncertainty in survey information and the ranking information of demographic and resource needs factors.

	Ranking Uncertainty		
Abundance Uncertainty	Low	Medium	High
Low	Low	Low	Medium
Medium	Medium	Medium	High
High	High	High	High

3.3 Current Condition: 3Rs

3.3.1 Resiliency

In this SSA, we have utilized the most recent and best available scientific data to evaluate population resiliency for AHTF in the U.S. and Canada. Currently, there are 144 extant populations, 32 in the U.S. and 112 in Canada across 177 recorded populations/EOs (Figure 3-2; Appendix A).[2] We conservatively estimate the total population of the AHTF to be approximately 122,000 plants, although the lack of recent surveys at 81 populations in Ontario and 1 population in Michigan that we believe to represent approximately 48,000 plants, increases our uncertainty for approximately 40 percent of the estimate (Figure 3-3).

Since the most recent reports from the Service (2012, entire) and COSEWIC (2016, entire), two populations have been determined to be extirpated, one in New York and one in Michigan, and four new small populations have been found, one in Michigan and three in Ontario. Three populations in New York, which were planted as part of a propagation program and are being monitored for long-term survival and reproduction, are included in our assessment of extant populations. Additionally, two populations in Michigan were formally surveyed for the first time following the preparation of these reports, and were found to be two of the largest populations in the U.S.

Of the 177-recorded populations/EOs, 11 populations are considered Historical by COSEWIC and 22 populations have been extirpated since surveys began for the species. Six of the 22 populations were extirpated in the 1920s and 1930s in New York and Ontario, primarily due to quarrying and logging, and 12 additional populations were extirpated from the 1960s through the 1990s, primarily due to logging and development activities in Ontario (Figure 3-4). Recent losses consist of three small populations in New York, Michigan, and Alabama since the mid-2000s. Additionally, 27 populations

[2] As a point of clarity, 139 populations have been considered extant based on previous reports, prior to this SSA, and our review of the available data has found that there are 144 extant populations. Our analysis below includes 139 populations, except these are the sum of all extant populations with available information *and* all extirpated populations. It is coincidence of numbers that previous reports had reported 139 extant populations and we utilized 139 populations in our analysis.

are considered extant but do not have any available survey data and are considered "Unknown." Therefore, we ranked the resilience of 117 populations of the AHTF. We found that among the 117 populations assessed, 30 populations (26 percent) were ranked High, 57 populations (49 percent) were ranked Medium, and 30 populations (26 percent) were ranked Low (Figure 3-5; Appendix B).

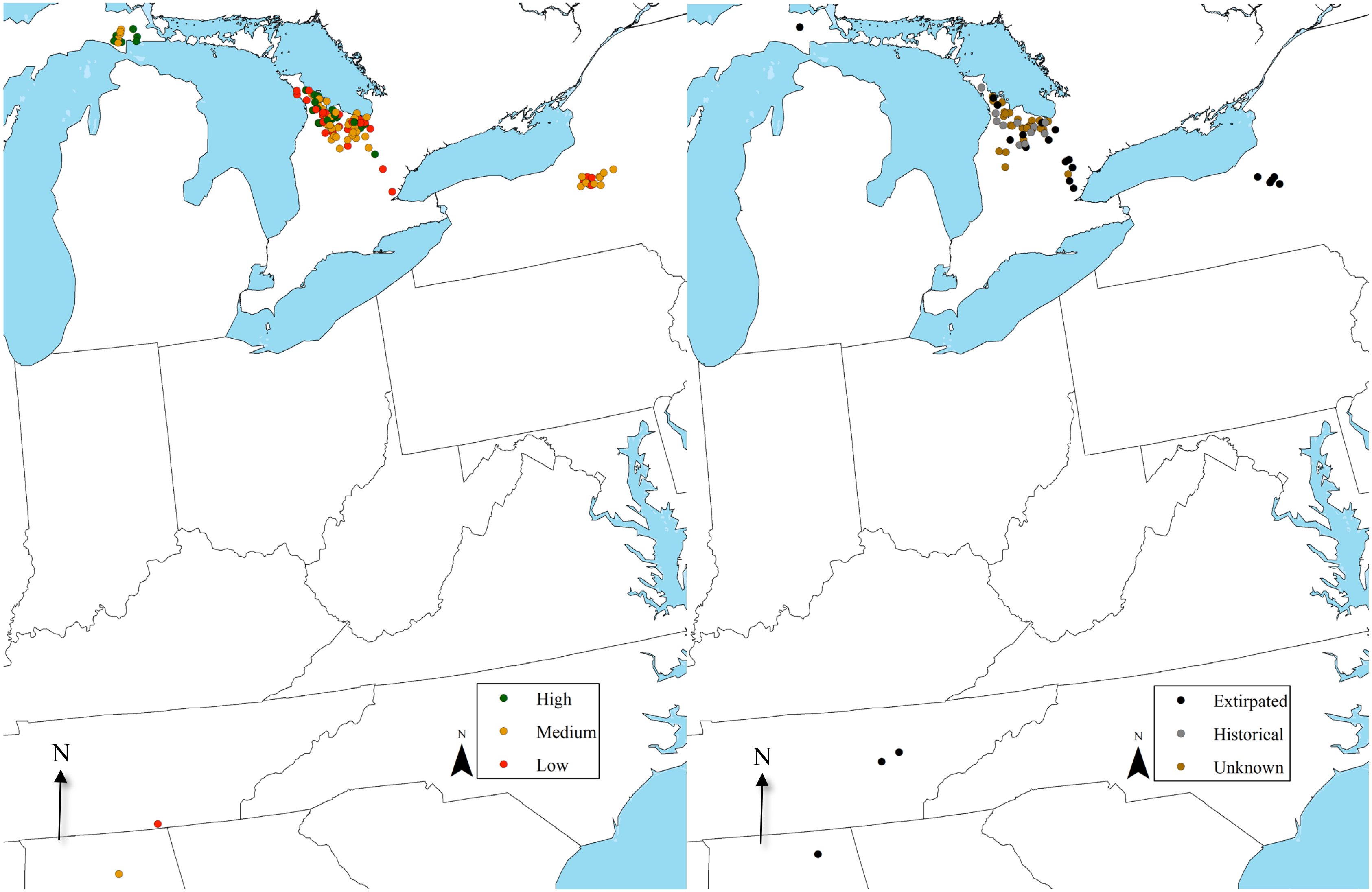


Figure 3-2. Maps of populations of the AHTF ranked for resilience (left) and [unknown](), [historical](), or extirpated populations (right) of AHTF in the U.S. and Canada. Site locations were generalized and then randomized across 0.01 decimal degrees of latitude and longitude to limit overlap. More detailed maps are presented in Section 3.3.4.

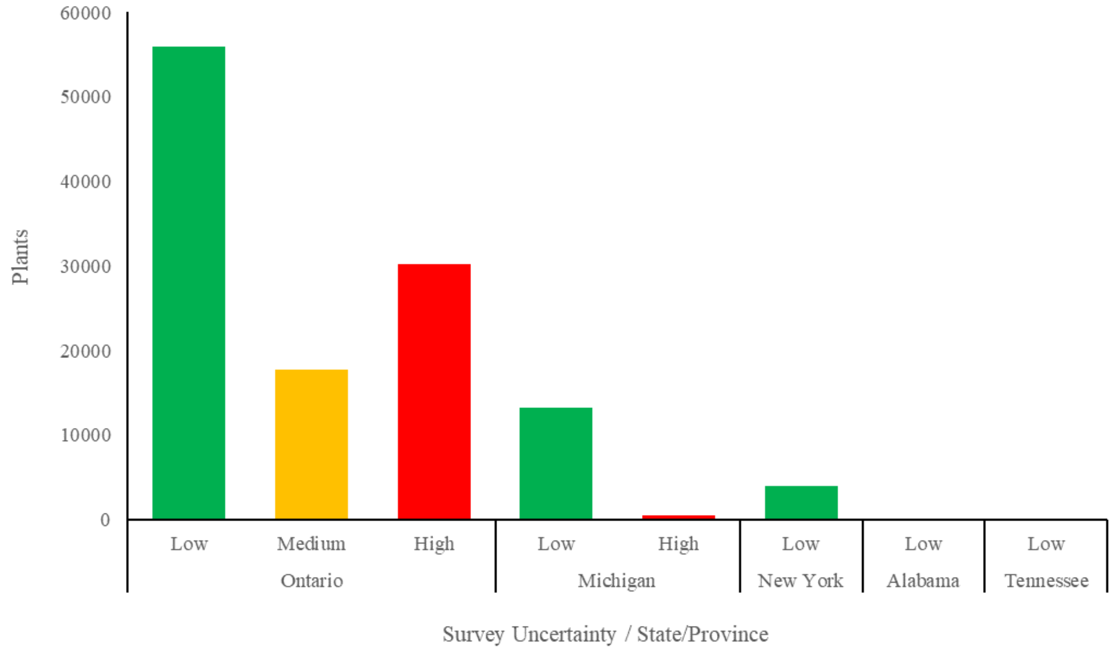


Figure 3-3. Number of plants survey uncertainty by State or Province. Survey uncertainty is low if surveys are recent (<10 years).

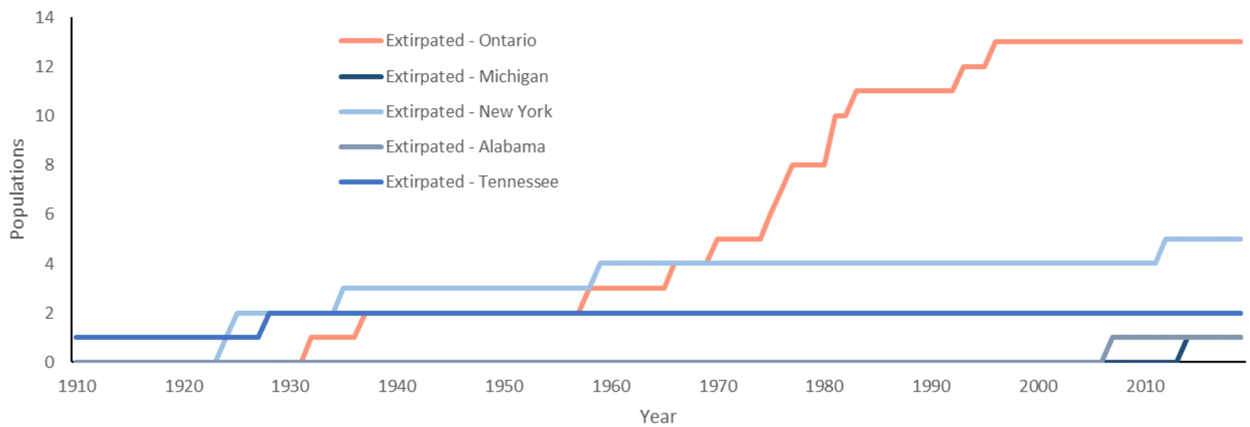
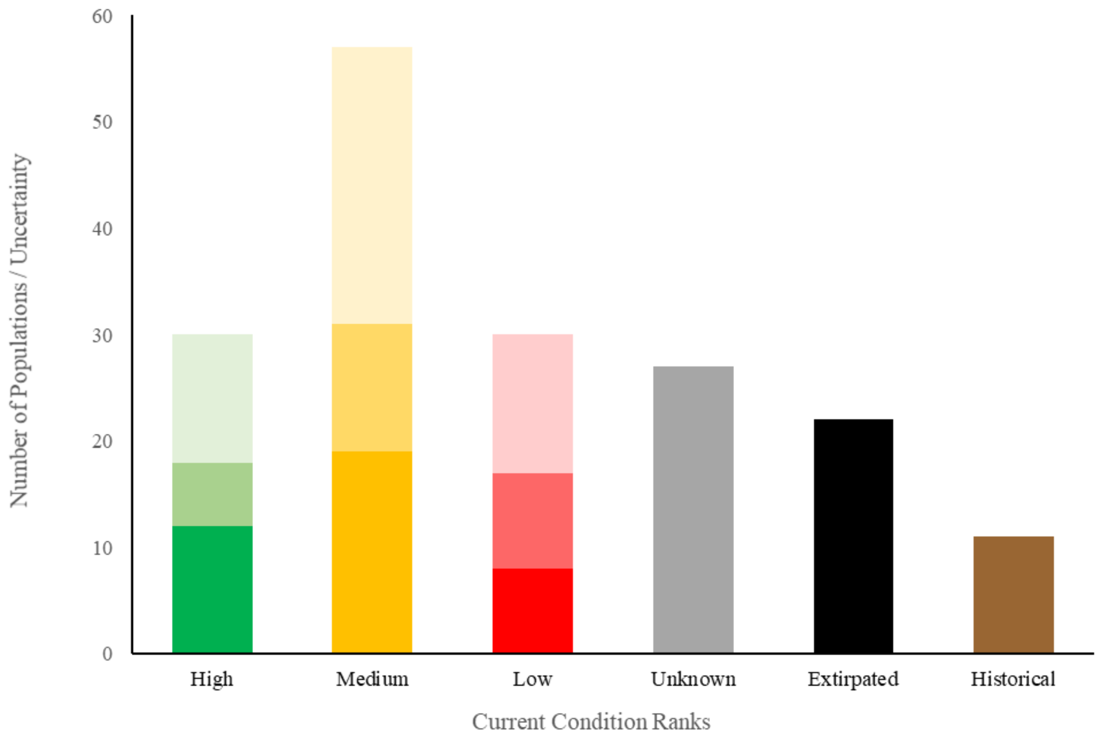


Figure 3-4. Cumulative known extirpations of the AHTF, by year of last observation or verified negative survey for each state or province.

We found that approximately 107,000 plants (88 percent) are located in populations with a High rank and approximately 13,000 plants (11 percent) are located in populations with a Medium rank (Figure 3-5). Approximately 900 plants are found in the 30 Low rank populations. The finding that a majority of the plants are in High rank populations is unsurprising as population size was one of the primary determinants of current condition in this SSA; however, it is clear that approximately 88 percent of the individuals of AHTF are in 26 percent of the populations. Four populations in Ontario have more than 10,000 individuals representing 48 percent of all plants across the range. Fifteen other populations have over 1,000 plants. In contrast, 43 populations (37 percent) have less than 100 individuals and have Low Abundance. Twenty-one of these populations (18 percent) have less than 20 individuals and are highly susceptible to extirpation.



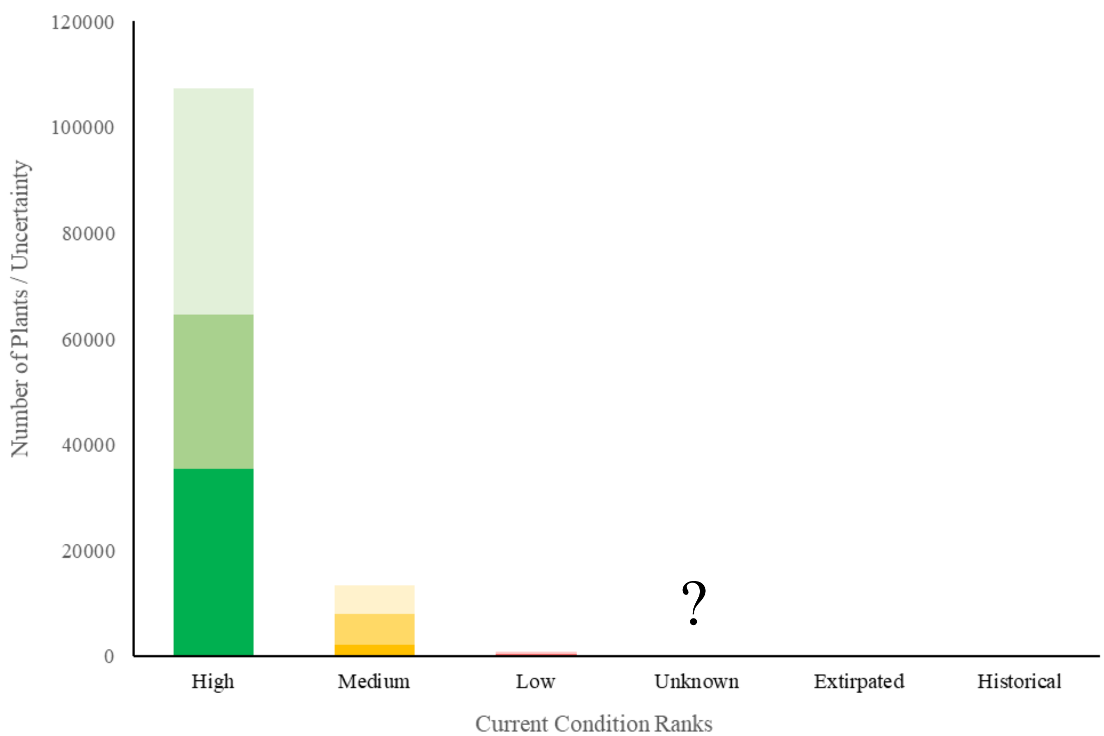


Figure 3-5. Summary of current condition by uncertainty for AHTF populations (above) and number of plants (below). Historical populations may have individuals of the AHTF present, although no data are available to determine their abundance. Lighter shading indicates higher uncertainty.

State and provincial trends in current condition appear to follow that for the AHTF as a whole (Figure 3-6). Ontario represents the considerable majority of all populations in each population rank and 73 percent of all populations of the AHTF. Ontario also represents two-thirds of the High rank populations (20 total) and 72 percent of the Medium rank populations (41 total). Michigan and New York are the only States that have High rank populations with 6 and 4 populations, respectively (Figure 3-6). While Michigan has a similar number of Medium rank populations, proportionally more New York populations are of Medium rank. Overall, Michigan has fewer (12 total) populations than New York (18 total), but the Michigan populations trend toward higher population ranks when compared to the New York populations. The only extant populations in Alabama and Tennessee are ranked Medium and Low, respectively (Figure 3-6).

As described above, the majority of all plants are located in a few to several large populations (400 – 10,000+ individuals). Approximately 104,000 plants (85 percent of all the AHTF) are located in Ontario with approximately 90,600 (74 percent of all the AHTF) located in the 20 High rank populations (Figure 3-6). Michigan and New York both have High Abundance populations with approximately 4,000 to 7,000 and 1,000 to 2,000 plants, respectively, across two populations in each state (Figure 3-6). However, the majority of all populations across the species' range are Medium and Low Rank and consist generally of few plants. The 87 Medium and Low rank populations only contain 11 percent of the plants, mostly in Medium rank populations in Ontario. The only extant populations in Alabama and Tennessee are both small, and particularly for Tennessee (3 plants recorded in 2017), susceptible to extirpation.

Uncertainty in our rankings tended to be either Low or High within the resiliency ranks. Forty-one populations (35 percent) had Low uncertainty in their rankings (Figure 3-5). All populations in the U.S. except one in Michigan had Low uncertainty and only 8 populations in Ontario had Low uncertainty. The lack of recent survey data or information regarding habitat factors in Canada limited our certainty for these populations (Figure 3-3; Appendix B). While 42 populations in Ontario have had surveys since 2010, 81 populations have not had recent surveys or have only descriptive estimates of population numbers. Only populations in Ontario with recent surveys and some available information on the ranking factors had Low uncertainty.

In order to compare our rankings of current condition with additional available information, we compared our populations ranks against the NatureServe rankings (unpublished data, Austen 2000, pp. 36–55; NatureServe 2002, entire) of each population (Figure 3-7). NatureServe ranks range from A-D (Excellent – Poor) and include a variety of factors in an overall assessment of condition, although these factors are usually not provided with the ranking. We found that, in general, the two methods correspond well in that the majority of High ranked populations tend to be A-B ranked and the majority of the Low ranked populations trend to be C-D ranked. Approximately 25 populations did not have readily available NatureServe Rankings. However, in Canada, our rankings tended to be more conservative for Medium ranked populations, largely due to our definition of greater than 400 plants as High Abundance and the incorporation in this SSA of more recent information since the rankings were produced. In the U.S., several High ranked populations were ranked B-C, but maintained a high rank in our assessment due to the ample available data and our assessment of the habitat factors at the populations. We consider our rankings to be well-informed in the U.S.; however, our rankings in Canada may be conservative compared to the NatureServe rankings at the upper end, which is appropriate given the relative uncertainty in the data. Several Unknown populations have had EO ranks given, some of which are in the Good to Moderate (B-C) ranks.

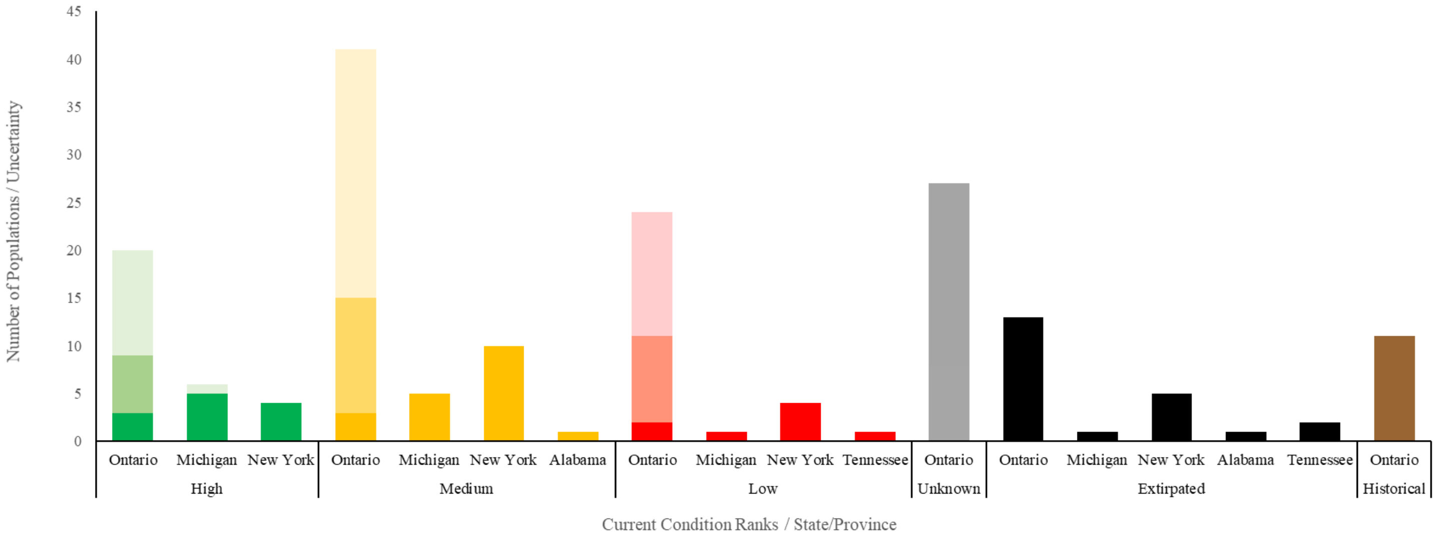


Figure 3-6. Summary of population resilience by State or Province and uncertainty for the AHTF populations (above) and number of plants (below). Unknown populations may have individuals of AHTF present, although no data are available to determine their abundance. Lighter shading indicates higher uncertainty.

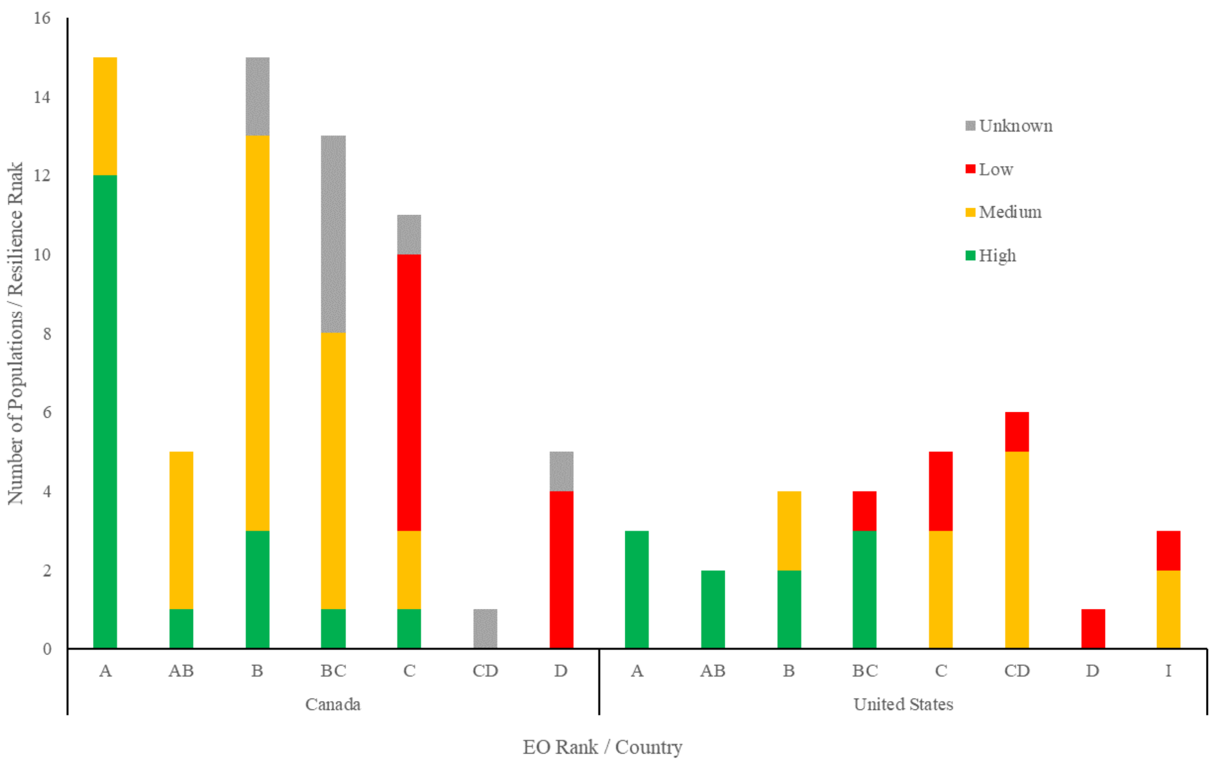


Figure 3-7. Number of populations by resilience rank (High, Medium, Low, and Unknown) and NatureServe ranks (A – D) for AHTF populations in the U.S. and Canada.

3.3.2 Representation

Representation is the ability of the species to adapt to physical (e.g., climate conditions, habitat conditions, or structure across large areas) and biological (e.g., novel diseases, pathogens, predators) changes in its environment presently and into the future; it is the evolutionary capacity or flexibility of the species. Representation is the range of variation found in a species, and this variation, called adaptive diversity, is the source of species' adaptive capabilities. Representation for the AHTF can be described in terms of variability among environmental settings and genetic diversity and can be measured by the number of resilient populations in each representative unit. Representation for the AHTF can be described based on readily available differences in genetics (Section 2.6.) and ecological settings (Section 2.4).

For the purposes of this SSA, we determined that the breadth of adaptive capacity can be captured by distribution of populations of AHTF within two representative units (one with two sub-units). We chose these representative units based primarily on the genetic and ecological distinctiveness of the southern populations of AHTF when compared to those in the northern portion of the range. The southern populations are within the Appalachian Region of the U.S., where they are associated with limestone sinkholes and cave entrances, generally known as karst features. These karst features exclusively provide the cool, moist microclimate on which the AHTF depends. Genetic analyses including the southern populations (Fernando 2018, pp. 6–7; Weber-Townsend 2017, pp. 44, 60–61) have found that samples from Alabama are more distinct from the northern populations than the northern populations are from themselves, while the genetic information from Tennessee is inconclusive (Figure 3-8). We have classified the southern populations as the Appalachian Karst representative unit.

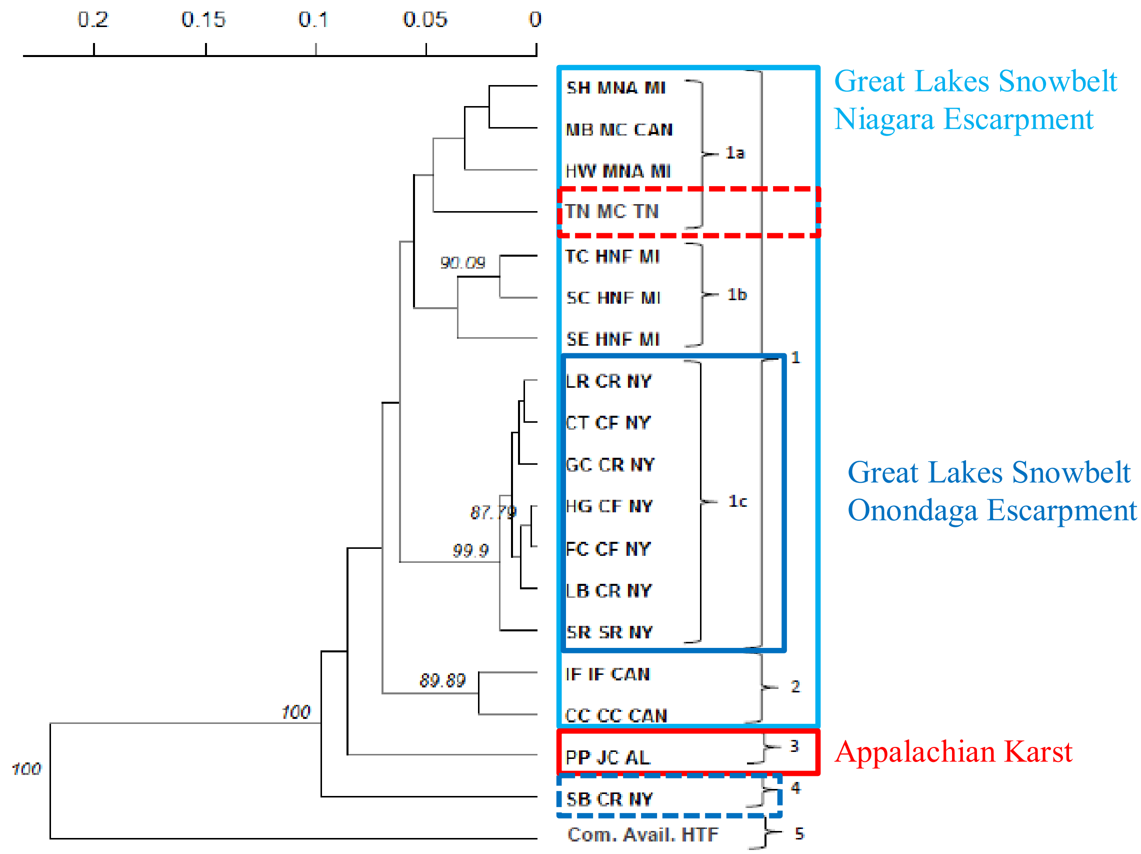


Figure 3-8. Unweighted pair group method with arithmetic mean dendrogram of AHTF and commercially available hart's-tongue fern (Com. Avail. HTF) relationships based on simple sequence repeats (SSR, i.e., microsatellites) and ISSR markers (see Section 2.6). Figure from Weber-Townsend (2017, p. 44). Note, that while SB CR NY is a population from New York in the Great Lakes Snowbelt representative unit, genetic information has consistently shown that the population is distinct and more diverse than other New York populations and more similar to commercially available hart's-tongue fern. Also, note that TN MC TN is the population in Tennessee and in the Appalachian Karst representative unit; however, the genetic samples for this population were obtained from only one frond and there is a report that spores from Owen Sound, Ontario, were introduced (McGilliard 1936, p. 120). There is a high amount of uncertainty in the genetic results related to this population.

The northern populations are closely associated with the heavy snowfall areas of the Great Lakes Region of the U.S. and Canada (see Figure 2-6). The heavy snowfall areas, or snowbelts, are hypothesized to provide protection from frost damage and increased soil moisture during critical growth periods during spring melt. The populations occur in association with limestone bedrock escarpments and associated glacially formed geomorphic features. Genetic analyses generally do not support the segregation of any separate representative units within the northern portion of the range, as populations from Michigan, New York, and Ontario do not form distinctive clusters outside of the overall Great Lakes Region (Figure 3-8). We have classified the northern populations as the Great Lakes Snowbelt representative unit.

We have recognized that although the genetic information does not support a separate representative unit for populations from New York, these populations are distinctive within the larger Great Lakes Snowbelt unit. All of the populations from New York, except one (as described in Figure 3-8), cluster together within the larger clade, excluding any populations from Michigan or Ontario, while populations from the latter two areas cluster together within a larger clade with the populations in New York (also see Fernando et al. 2015, p. 30). Two bedrock escarpments are known to occur in association with the AHTF in the northern portion of its range. The Niagara Escarpment extends from Wisconsin, through the Upper Peninsula of Michigan, through Manitoulin Island, south-central Ontario, and extends into western New York; however, this escarpment does not extend to the populations of the AHTF in New York. The New York populations are associated with the Onondaga Escarpment, which travels through the western portion of south-central Ontario through New York, south of the Niagara Escarpment, extending into central, eastern, and southeastern New York. We have classified the New York populations of the AHTF as the Onondaga Escarpment sub-unit and the Michigan and Ontario populations as the Niagara Escarpment sub-unit of the Great Lakes Snowbelt unit. While we do not consider the populations from New York to represent a distinct unit of adaptive capacity, the relative uniqueness of the populations are highlighted by our sub-unit designation and can help prioritize future management decisions across the northern portion of the range.

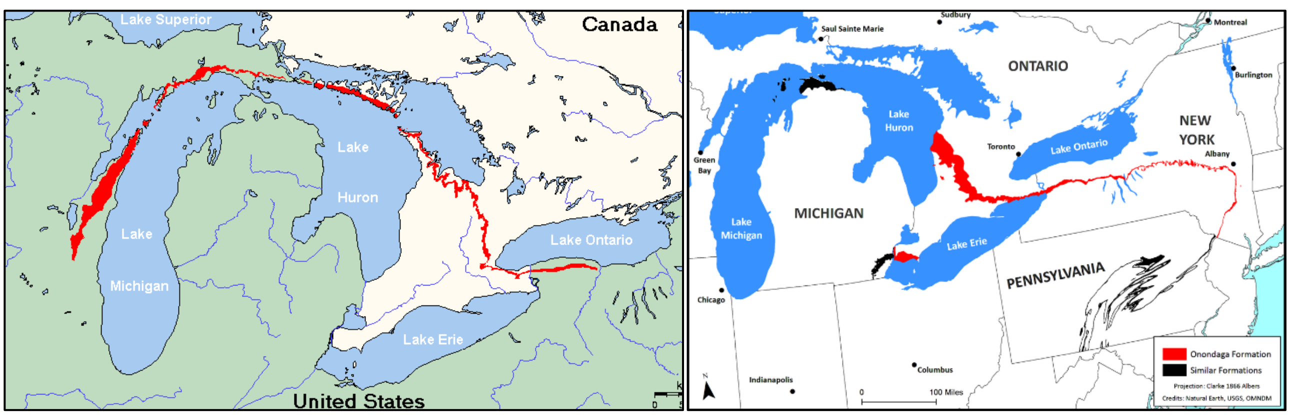


Figure 3-9. Location of the Niagara (left) and Onondaga (right) Escarpments in the Great Lakes Region. en.wikipedia.org, accessed August 23, 2019. Niagara Escarpment image usage permission under the terms of the GNU Free Documentation License. Onondaga Escarpment image by J. G. Van Hoesen - Previously unpublished. Provided by author for uploading.

The two representative units described in this SSA are intended to reflect the adaptive capacity of the AHTF, especially in light of the most recent glacial period. During the most recent glacial period, the entirety of the Great Lakes Snowbelt unit would have been covered by the glacial front; therefore, all populations in this representative unit must have reestablished in the time since the glacial retreat. The Appalachian Karst populations were never covered by glacial ice and may have been more widespread in the southern portion of its range when cooler temperatures prevailed in the Northern Hemisphere. The Appalachian Karst populations may be the remnant of the original pre-glacial AHTF in the U.S. and Canada. This adaptive capacity to persist in southern locations may have been a fundamental mechanism behind the survival of this species during changing climatic conditions.

We acknowledge our uncertainty regarding our classification of representative units for the AHTF. The lack of extensive genetic information from Canada and the limited quantity and potential contamination of the Tennessee population (Figure 3-8) further confound this issue. Only three populations in Canada have been included in genetic analyses. These represent three of the larger populations in Ontario, and likely do not represent the full range of genetic variation in Canada. While we have classified the New York populations as a distinctive sub-unit of the Great Lakes Snowbelt associated with the Onondaga Escarpment, the Onondaga Escarpment also occurs in south-central Ontario. Several Unknown populations have been located along this unit in Ontario; however, no genetic information is available from these populations.

Additionally, the Ontario populations have a range that extends from the Lake Huron basin (with Michigan) to the Ontario basin (with New York). The Ontario populations are physiographically separated from the Michigan populations by Manitoulin Island, where the AHTF does not occur. Manitoulin Island receives less snow cover than other areas in Great Lakes Snowbelt (see Figure 2-6), but also has generally unsuitable habitat due to a lack of deciduous canopy resulting from the high wind exposure of the Niagara Escarpment there and an extensive fire history (J. Jones, pers. com.). Analyses utilizing chloroplast DNA have shown that the larger populations in Michigan are distinct compared to other Michigan or Canadian populations (Fernando 2018, pp. 6-7).

Overall, representation is Low for the AHTF, as would be expected for a narrow habitat specialist species. There is some genetic variation across the range but it is generally low. In addition, nearly all individuals occur in association with a variety of similar habitats associated with limestone bedrock, cool microsites, and closed canopy cover. However, populations are distributed widely over many hundreds of miles and there may be additional ecological differences that we have yet to describe. The AHTF has two distinct representative units that suggest there may be adaptive capacity across the species' range; however, one of these units may have always been rare under current climatic conditions. While the Appalachian Karst Unit is distinct genetically and ecologically, we are uncertain what adaptive capacity may be found in the southern populations or what the overall impact the potential loss of this unit may have for the AHTF, generally.

3.3.3 Redundancy

Redundancy describes the ability of a species to withstand catastrophic events by maintaining multiple, resilient, populations well-distributed within the species' ecological settings and across the species' historical range (Wolf et al. 2015, pp. 204–205). The catastrophic event of concern for northern populations of AHTF is drought and canopy loss due to tree fall or defoliation events. We are unaware of any potential catastrophic events in the southern portion of the range.

We have summarized the redundancy of populations among the representative units and sub-units of the AHTF across the species range (Table 3-4). Overall, the Great Lakes Snowbelt unit contains nearly all of the populations and individual plants. While there are gaps in the distribution of this unit, at Manitoulin Island and across the Niagara Peninsula and parts of western New York, it is likely that the AHTF has not occurred in these areas in the past 100 years or more. These areas receive lower snowfall amounts (Figure 2-6) or have lower quality habitat when compared to locations of the extant populations. As a whole, this representative unit has 142 populations and appears to have a high number of resilient, well-distributed, populations and was determined to have

High redundancy, as no catastrophic event is likely to simultaneously affect so many well-distributed populations.

Table 3-4. Redundancy of AHTF by representative unit.

Representative Unit (Subunit)	State(s)/Province	Redundancy (Number of extant populations)	Populations Extirpated or Historical	Rank
Great Lakes Snowbelt	ON, MI, NY	142	30	High
Niagara Escarpment	ON, MI	124	25	High
Onondaga Escarpment	NY	18	5	Low
Appalachian Karst	TN, AL	2	3	Very Low

Within the sub-units of the Great Lakes Snowbelt, the Niagara Escarpment sub-unit contains the considerable majority of all populations of the unit, as a whole. Approximately 87 percent of all populations in the Great Lakes Snowbelt are located in this sub-unit and the sub-unit is still well-distributed across south-central Ontario and Michigan. With 124 populations within this sub-unit, catastrophic events are again unlikely to negatively affect multiple populations simultaneously and the sub-unit was determined to have a High rank for redundancy.

In contrast, the Onondaga Escarpment Sub-unit of the Great Lake Snowbelt has relatively few populations concentrated primarily in two adjacent counties in New York. The majority of these populations occur in close proximity to one another in one location. Additionally, nearly a quarter of the total known populations in this sub-unit are considered Extirpated. With only 18 extant populations, a relatively high number of extirpated populations, and the majority of all populations in the sub-unit occurring in one location, even a localized catastrophic event is likely to negatively affect the species in this portion of its range. The sub-unit was determined to have a Low rank for redundancy.

The Appalachian Karst representative unit is depauperate in the number of populations found within it. Only two extant populations remain, and based on the number of known records, the AHTF may never have been extensively distributed in the previous 100 years. As a catastrophic event could eliminate half to all of the populations in this representative unit, and the majority of all known populations are already extirpated, this representative unit was determined to have Very Low redundancy.

We have low uncertainty in our assessment of redundancy in the U.S. as nearly all populations have recent survey information. However, our uncertainty in Ontario is generally higher. In Ontario, 27 populations have be ranked as Unknown and an additional 40 have High uncertainty in their survey information due to a lack of recent surveys. This represents over half of the populations in Ontario. However, it is unlikely that a large number of these populations have been extirpated based on recent known historical losses of populations in Canada, so our assessment of redundancy in the Niagara Escarpment Sub-unit appears to be reasonable. Overall, redundancy for the AHTF is High in the northern portion of the range, with lower redundancy in New York, and is Very Low in the southern portion of the range.

3.3.4 Synthesis

A species' current condition, as presented in this SSA, is an assessment of the current resilience, representation, and redundancy of the species (Smith et al. 2018, p. 206). For the AHTF, we have assessed the 3 Rs above and summarized them in Table 3-5 and Table 3-6. The AHTF has two representative units between the northern Great Lakes Snowbelt and the southern Appalachian Karst and redundancy is High and Very Low in each unit, respectively.

Table 3-5. Summary of Current Condition 3Rs by population for the AHTF.

			Resiliency					
Representative Unit (Subunit)	State(s)/Province	Redundancy	High	Medium	Low	Unknown	Extirpated	Historical
Great Lakes Snowbelt	ON, MI, NY	High	30	56	29	27	19	11
Niagara Escarpment	ON, MI	High	26	46	25	27	14	11
Onondaga Escarpment	NY	Low	4	10	4	0	5	0
Appalachian Karst	TN, AL	Very Low	0	1	1	0	3	0

Table 3-6. Summary of Current Condition 3Rs by number of individuals for the AHTF.

			Resiliency					
Representative Unit (Subunit)	State(s)/Province	Redundancy	High	Medium	Low	Unknown	Extirpated	Historical
Great Lakes Snowbelt	ON, MI, NY	High	107375	13431	851	?		
Niagara Escarpment	ON, MI	High	104092	12826	739	?		
Onondaga Escarpment	NY	Low	3283	605	112			
Appalachian Karst	TN, AL	Very Low	0	30	3			

The Great Lakes Snowbelt has two sub-units between the Niagara Escarpment in Ontario and Michigan and the Onondaga Escarpment in New York. Redundancy in the Niagara Escarpment Sub-unit is considered High as the populations are widely distributed across the eastern portion of the Upper Peninsula of Michigan and south-central Ontario (Figure 3-10). However, there have been geographical reductions in redundancy on the western and southern edges of the range in Ontario with extirpations or lack of recent survey information in these regions. This sub-unit contains the largest populations, the considerable majority of all populations rangewide, and the majority of the High resilience populations of the species. The majority of the populations have a Medium resiliency.

The Onondaga Escarpment sub-unit is much smaller when compared to the other northern populations. Redundancy in the Onondaga Escarpment Sub-unit is considered Low as the populations are relatively narrowly distributed and the majority are located in one localized area centered around a single state park. (Figure 3-11). The extirpation of several populations in the middle of the range in New York has decreased the overall redundancy of the sub-unit by approximately 25 percent. The majority of the populations are ranked Medium, and while there are several High resiliency populations, these are not as large or extensive as the populations in Ontario and Michigan.

The Appalachian Karst Representative Unit is the smallest, most unique, and most vulnerable of the representative units of the AHTF. Redundancy for the unit is considered Very Low as there are only two remaining populations and the majority have been extirpated over time (Figure 3-12). The only two remaining populations are of Medium and Low resiliency.

Our uncertainty with current condition reflects our overall uncertainty in the survey, habitat, and genetic data available for the SSA. We have Low uncertainty regarding our assessment of the current condition of the Appalachian Karst unit, Great Lakes Snowbelt Onondaga Escarpment sub-unit, and the Michigan populations of the Niagara Escarpment sub-unit due to our Low uncertainty with the population rankings and available habitat and genetic information. The Ontario populations of the Niagara Escarpment sub-unit generally had higher uncertainty and less available genetic information and, therefore, our assessment of the 3Rs for these populations may be more prone to error. The available data do indicated that, despite additional uncertainty, there are a considerable number of populations and plants in Ontario.

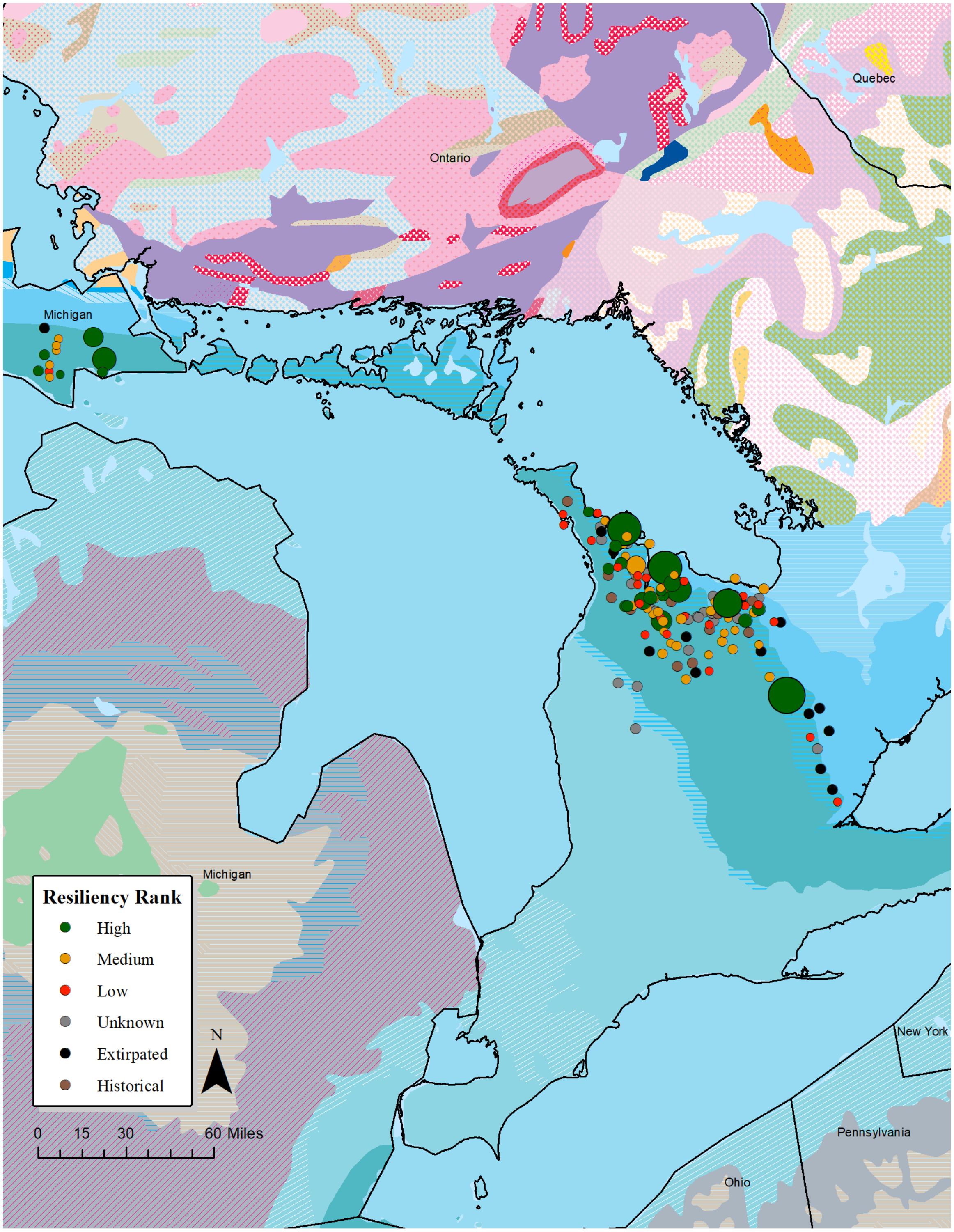


Figure 3-10. Map of the current condition of the Great Lakes Snowbelt: Niagara Escarpment Representative Sub-unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the teal green color underneath the majority of the populations represents the limestones associated with the Niagara Escarpment. The lighter blue green under the three Unknown populations represents the limestones associated with the Onondaga Escarpment. Locations have been randomized across 0.01 degrees of latitude and longitude.

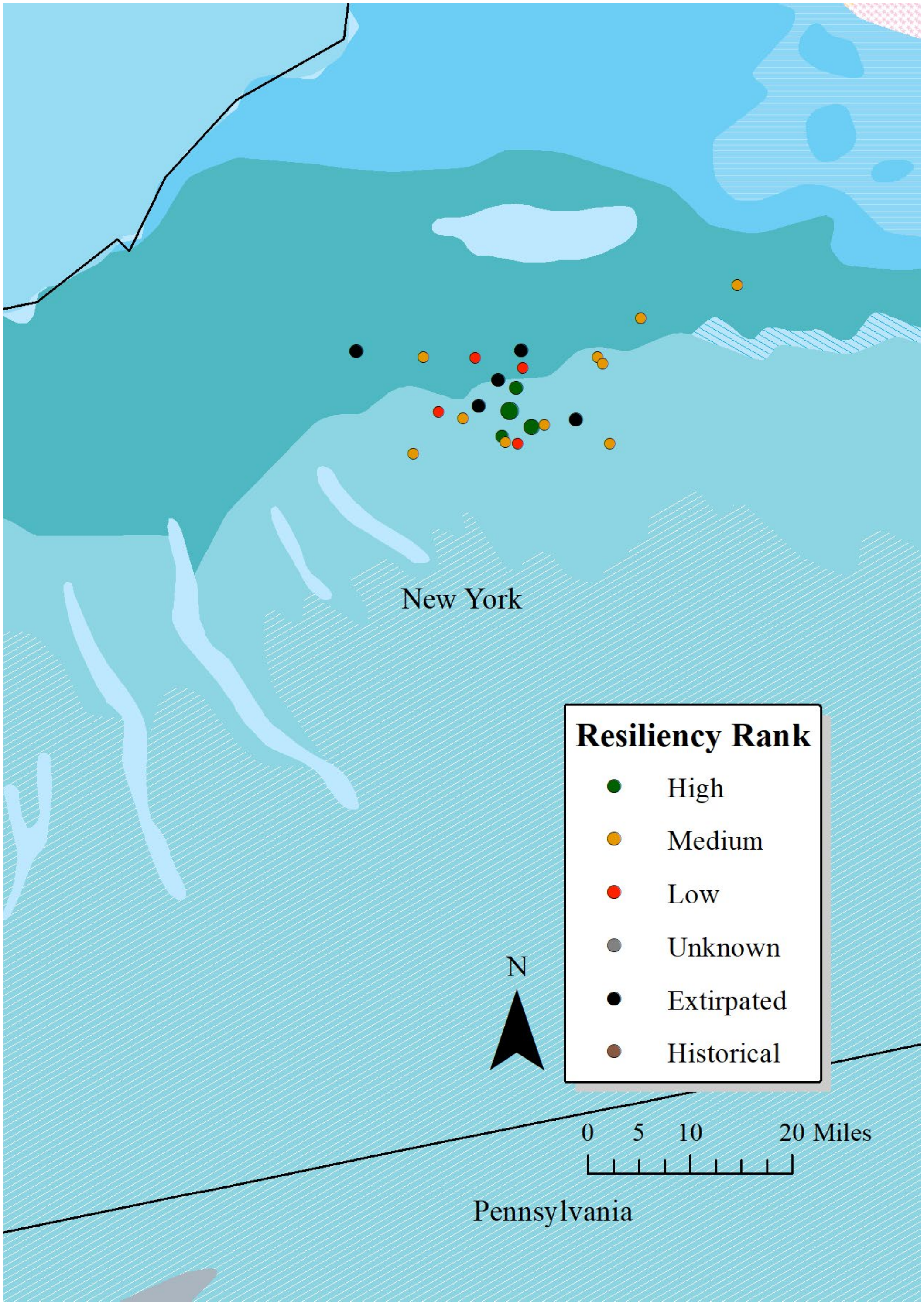


Figure 3-11. Map of the current condition of the Great Lakes Snowbelt: Onondaga Escarpment Representative Sub-unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the contact between the two blue green layers generally represents the dolostones associated with the Onondaga Escarpment. Locations have been randomized across 0.01 degrees of latitude and longitude resulting in some shifting north and south of this boundary in the image.

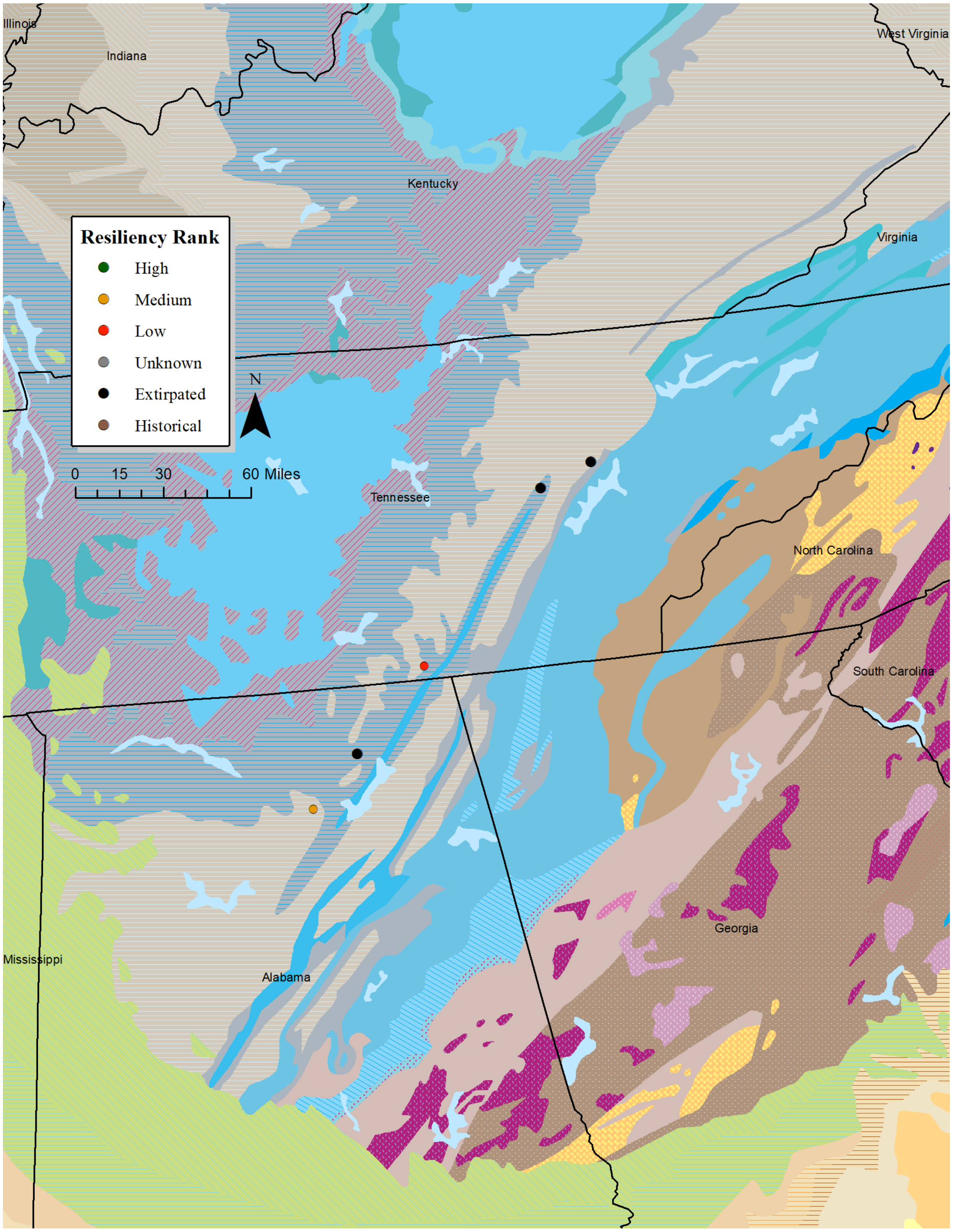


Figure 3-12. Map of the current condition of the Appalachian Karst Representative Unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the blue colors represent the limestones associated with the southern Appalachian Karst Unit. Locations have been randomized across 0.01 degrees of latitude and longitude resulting in some shifting away from these units in the image.

4 FACTORS INFLUENCING VIABILITY

Based on the AHTF's life history and habitat needs, we identified the potential negative and positive influences and the contributing sources of those influences that are likely to affect the species' viability (Table 4-1; Figure 4-1). The primary factors influencing AHTF population viability are those factors that alter population abundance (i.e. resilience) either by directly impacting the species or by impacting the species' resource needs (i.e. habitat). The number of populations affected and degree of influence of these factors determine their impact on the species as a whole, across the species' range (i.e. redundancy), and within any unique environmental settings or genetic lineages (i.e. representation).

Table 4-1. Factors influencing AHTF viability at the individual, population, and species levels.

Stressor	Individual	Population	Species (multiple populations)
Climate Change	X	X	X
Invasive Species	X	X	X
Logging	X	X	X
Quarrying	X	X	X
Development	X	X	X
Recreation	X	X	
Collection	X	X	
Herbivory	limited		
Disease	unknown		

4.1 Logging

Habitat loss is considered the greatest threat to many rare species both in the U.S. (Wilcove et al. 1998, p. 607) and Canada (Venter et al. 2006, p. 906). The AHTF occurs exclusively under dense, shaded, deciduous forest canopy. Loss of the forest canopy through logging increases thermal stress, increases available moisture, and can limit bryophyte communities associated with successful reproduction of AHTF (Collins and Pickett 1987, p. 8) (Figure 4-1). Logging can also cause direct impacts to the AHTF through trampling and crushing and through the introduction of invasive species (Section 4.4). Weedy native species may also become abundant after disturbance, potentially competing with the AHTF for light and substrate resources (COSEWIC 2016, p. 27).

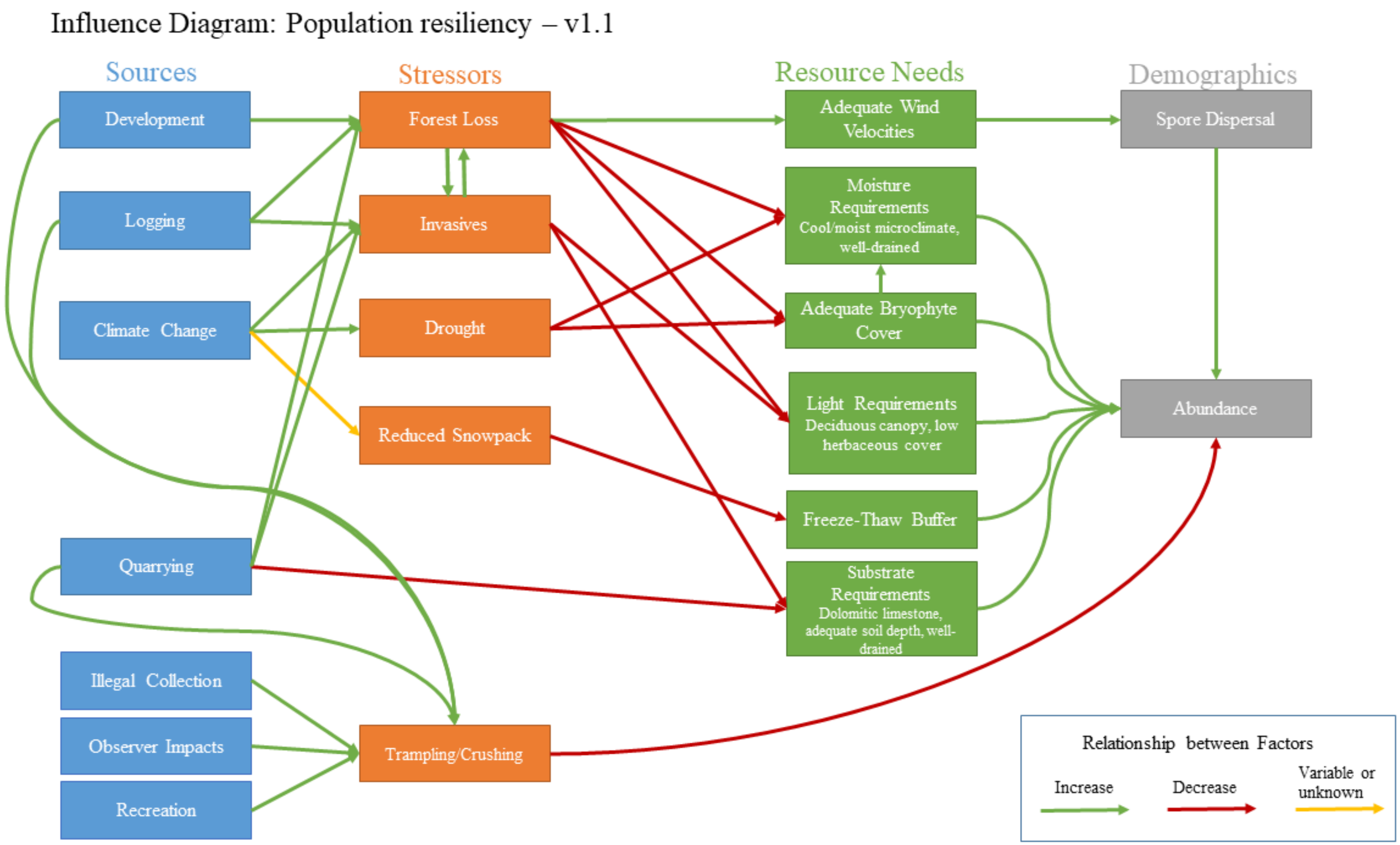


Figure 4-1. Influence Diagram for AHTF modeling sources, stressors, resource needs of the species, and their impact on species demographics. Species demographics were focused on population level abundance (i.e., resilience).

The majority of forested habitats in the range of the AHTF in the U.S. and Canada were cleared for agriculture in the middle to late 19th century with nearly all remaining forests having been cleared or selectively cut for timber (Nyland et al. 1986, entire; Tchir et al. 2009, pp. 215–220). However, the rocky and sometimes steep nature of the terrain where the AHTF occurs is not well suited for intensive agriculture and makes harvesting timber difficult where steep slopes occur. Areas with less steep slopes where the AHTF occurred were sometimes cleared and pastured (Paine 1866, p. 282). Subsequent regrowth of the eastern forest has resulted in more extensive areas of second-growth forest with varying suitability for the AHTF. Generally, the AHTF was lost from areas that were heavily harvested and subsequent forest regrowth in these areas frequently contains a dense understory (often of invasive species; see Section 4.4) unsuitable for survival of the AHTF. In some areas where residual habitat remained following less intense clearing, the AHTF individuals and populations remained and potentially increased in number after forest regrowth. Logging remains a primary stressor for AHTF across its range for populations that are not protected from such activities. Logging is occurring adjacent to three populations in Michigan, not found on Forest Service lands, and at least 10 extant populations in Ontario are known to have been negatively impacted by logging. Impacts associated with logging contributed to the extirpation of at least 8 populations in Ontario.

Edge effects of forest clearing have been linked to declines and increases in invasive species occurrence at populations of the AHTF. While the majority of sites of the AHTF are on protected lands (Section 4.7), many populations may not have an adequate buffer to prevent impacts to habitat needs of AHTF from adjacent logging. Adjacent logging may increase light levels, increase moisture stress, and encourage the encroachment of invasive species (Cadenasso and Pickett 2001, pp. 94–96; Gehlhausen et al. 2000, pp. 30–32). These effects will vary with the proximity of the activity to the AHTF population, but closer activities are more impactful than distant ones.

4.2 Development

Areas in and around the AHTF habitat in New York and Ontario have been heavily developed and converted to residential or commercial uses since the turn of the 19th century, while habitats in Michigan, Tennessee, and Alabama are currently relatively contiguous forested areas less proximal to development pressures. While impacts to the AHTF from development can be similar to those for logging, in contrast, development involves forest conversion and does not allow for AHTF plants to potentially persist. At least 5 populations have been or have likely been extirpated in Ontario due to these developments. At least 25 development applications in Ontario have the potential to impact populations of AHTF (COSEWIC 2016, p. 26). Recent trends of clearing forest for construction of infrastructure for gas pipeline, wind, or solar generation to meet energy demands could also affect the species. The marginally productive and rocky sites that the AHTF occupies may be more suitable for such uses. A wind energy development adjacent to two sites in Michigan has been proposed that could increase edge effects on these populations (A. Bacon, Michigan Nature Association, pers. com.), although there is no current progress on this development. Two populations in Michigan and one in New York have been segmented due to the construction of linear projects associated with roads, pipelines, and transmission lines. Edge effects from developments are also a noted problem.

4.3 Quarrying

Quarrying has been noted to be prevalent on the limestone outcrops associated with AHTF (Graves 1911, pp. 70–71; Hagenah 1954, p. 5; House 1934, pp. 68–69). Quarrying fundamentally alters the habitat for the AHTF by removing the limestone substrate, forest canopy, and cool microsites on which the species depends (Figure 4-1). Quarrying has historically been a threat to the AHTF in New York and quarrying caused the extirpation of three larger New York populations (Faust 1960, pp. 57–61) (Figure 4-2). Two populations have been lost in Ontario due to quarrying and at least five applications for aggregate mining since 2000 have included potential impacts to the AHTF (COSEWIC 2016, pp. 12–13). Quarries still operate in the vicinity of several populations in Michigan, New York, and Ontario. As recently as 2013, a population in Ontario was destroyed due to the expansion of a quarry, with ferns unsuccessfully transplanted to a new location (J. Jones, pers. comm.). Two populations in New York are located on quarry-owned property, although local zoning currently prevents the quarrying of the larger parcel on which they occur.

Figure 4-2. Aerial image of the Onondaga Escarpment in New York. The large quarry in the middle of the image removed three populations of the AHTF, and the majority of all AHTF populations in New York occur either to the east or west of this quarry.

Figure 4-3. Aerial image of the Niagara Escarpment in Ontario. The quarries in this image are immediately adjacent to two larger populations of the AHTF. Both quarries had development applications approved since 2010 and the western quarry was newly constructed since that time.

4.4 Invasive Species

Invasive species can negatively affect the AHTF either from direct competition with other plant species in the understory for light or substrate, or from invasive canopy pests that remove canopy cover, increasing light and decreasing humidity levels, both of which may adversely impact AHTF (Figure 4-1). Invasive species of concern include, but are not limited to, European swallowwort (*Vincetoxicum rossicum*), garlic mustard (*Alliaria petiolata*), dames rocket (*Hesperis matronalis*), European buckthorn (*Rhamnus cathartica*), honeysuckle (*Lonicera spp*), barberry (*Berberis* spp.), multiflora rose (*Rosa multiflora)*, and autumn olive (*Elaeagnus umbellata*) (COSEWIC 2016, p. 27; NYSOPRHP 2018, p. 4). Invasion of AHTF habitat by exotic understory plant species poses a serious threat to 16 of AHTF populations in the U.S. and has been reported at 7 populations in Ontario (COSEWIC 2016, p. 27).

In Ontario, Canada, the threat of invasive plant species to AHTF was listed as "low" for most populations in 2013 (Environment Canada 2013, pp. 6–10). Subsequent reports still list the threat of invasives as "low," but have noted that sprawling patches of garlic mustard and increasing numbers of European buckthorn are now present at many AHTF sites in Ontario. The increasing presence of invasive plants, in combination with other threats, have led to a "slight decline in habitat suitability, which will likely continue into the future," according to the report (COSEWIC 2016, pp. 20–28). Terrestrial invasive plant species do not appear to be a major threat to AHTF populations in Alabama, Tennessee, or Michigan, at present.

We evaluated the relative threats posed by invasive understory species and have determined that European swallowwort is currently the primary species that could affect population level dynamics of the AHTF. Threats from the remainder of the understory invasive species listed above generally originate from disturbances in or immediately adjacent to the populations, and if sufficient suitable habitat remains for the AHTF, these species are not strong understory competitors in the humid, lower light levels preferred by the AHTF. However, European swallowwort is known to spread heavily under intact forest canopies and be aggressive understory competitors with allelopathic properties that inhibit the germination of AHTF spores, likely by altering the soil chemistry to be more favorable for the germination of European swallowwort seeds (unpublished data, E. Watkins, Colgate University).

European swallowwort is of particular concern due to its ability to rapidly invade and establish dense, monocultural stands in shallow soils of shaded forest understories in New York (Douglass et al. 2009, p. 270) (Figure 4-4). European swallowwort has been observed to occur in and on the boulders and steep slopes associated with the AHTF, and this species appears to have a wide ecological niche associated with calcium-rich substrates. Large, dense stands of European swallowwort are present either directly within or in close proximity to nearly all AHTF populations in New York. The NYSOPRHP has regularly removed European swallowwort from most populations in New York and prevented significant declines; however, one population near Evergreen Lake is known to be heavily invaded and has declined from over 100 plants to 8 plants in 2017, with only 3 plants observed in 2019. European swallowwort has not been reported at any populations in Ontario, and it appears that most records of the species are south and east of the AHTF populations in Canada, although there are some limited records along the Niagara Escarpment. (Figure 4-5).

Figure 4-4. A dense stand of European swallowwort forms a near monoculture in the understory of a maple-basswood rich mesic forest within 30 feet of an AHTF in New York. Photo: NYSOPRHP, August 2018.

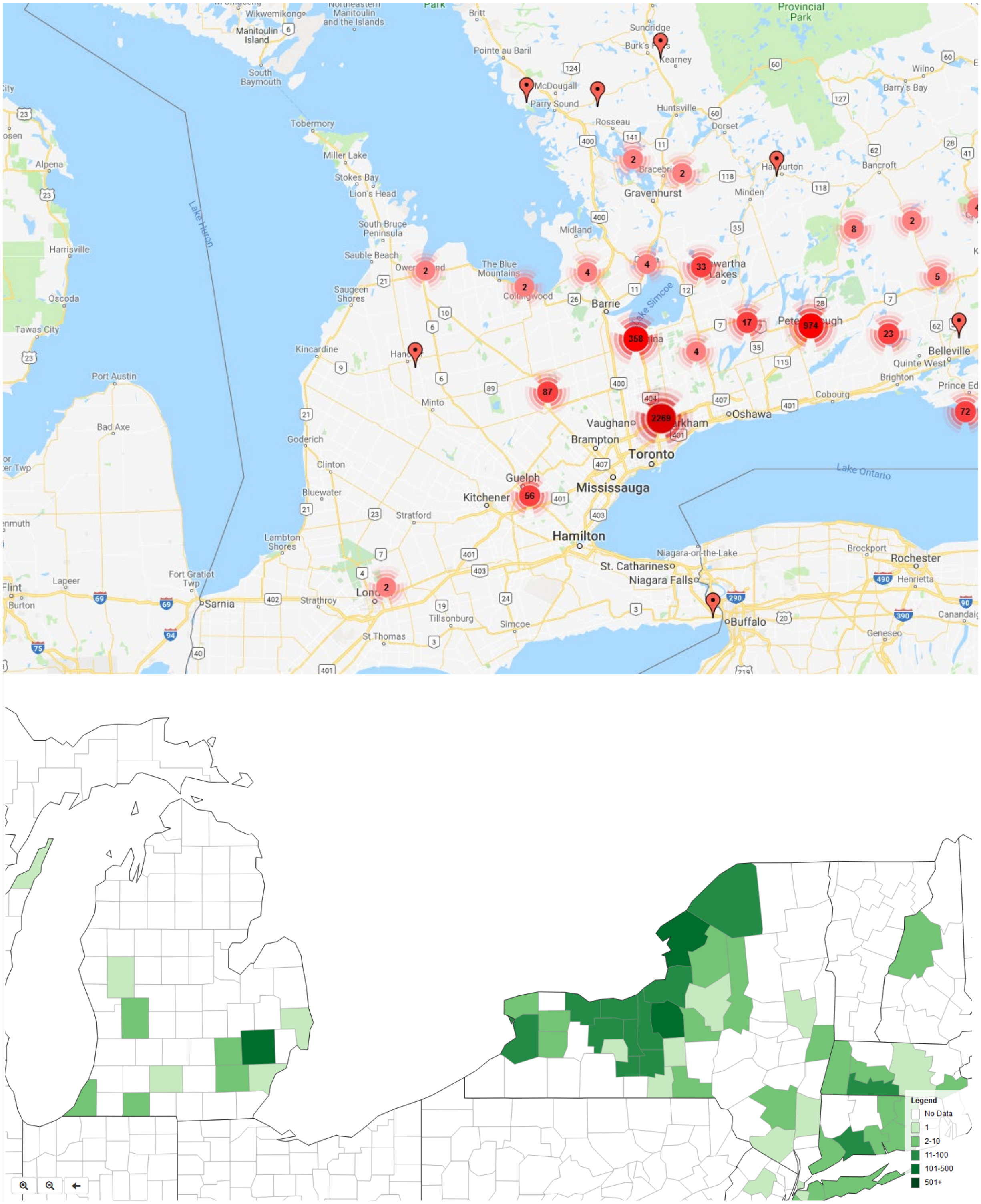


Figure 4-5. Distribution of public and citizen reporting of European swallowwort in the Great Lakes Snowbelt representative unit in Ontario (top) and the U.S. (bottom). Data from EDDMapS. 2019. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available online at http://www.eddmaps.org/; last accessed September 5, 2019.

Invasive forest pests are also a concern in many AHTF populations throughout the species' range due to their intense competition for both substrate and light resources, or their ability to damage or remove the forest canopy and increase moisture and thermal stress. The most recent AHTF status review notes that the emerald ash borer (*Agrilus planipennis*) and ALB are destructive to ash (*Fraxinus* sp.) and to sugar maples (*Acer saccharum*), respectively (USFWS 2012, p. 16). Emerald ash borer infestations have been confirmed at populations in New York, in some cases within 75 ft of AHTF populations (NYSOPRHP 2018, p. 13) and potentially in southern Ontario (J. Jones, pers. com.). In Michigan, leaf miners were reported to thin the tree canopy above one AHTF population in 1985, potentially causing a loss of humidity and soil moisture at the site that desiccated many individuals on the forest floor (USFWS 2012, pp. 15–16). Beech scale insect (*Cryptococcus fagisuga*), which causes beech bark disease, has been noted at populations across the northern portion of the range, although this species is a minor component of the forests where the AHTF occurs. Forest tent caterpillar (*Malacosoma disstria*) has been found to cause at least short-term impacts to populations in Ontario ((COSEWIC 2016, p. 27).

Invasive Asian jumping worms in the genus *Amynthus* have been positively identified in close proximity to at least one AHTF population in New York (NYSOPRHP 2018, p. 15). Potential impacts of the invasive worms on AHTF populations are currently unknown, but research suggests that the worms strip the leaf litter layer from forest floors, may be damaging to plant roots, and may create soil disturbances favorable for the establishment of invasive plant species (Greiner et al. 2012, pp. 5–10).

The rapidly spreading hemlock woolly adelgid (HWA) (*Adelges tsugae*) is known to be a destructive forest pest on native hemlock trees (*Tsuga* spp.) and was documented in Onondaga County, New York, at a site within 20 mi of the AHTF population at Split Rock Gulf. The AHTF generally do not grow directly underneath *Tsuga* spp. (Cinquemani Kuehn and Leopold 1993, p. 317), but conifers are commonly found growing within AHTF habitats and either occur in or contribute to the moist, humid microclimate that AHTF relies upon for reproduction and survival. The HWA poses limited threat to AHTF populations as the destruction of hemlock trees within the habitat may alter microclimates and create disturbances that favor the establishment of invasive plants in the vicinity, although we expect this effect to be localized only within some populations in New York (Figure 4-6). The removal of small amounts of conifer cover may actually benefit the AHTF due to reductions in non-deciduous canopy cover.

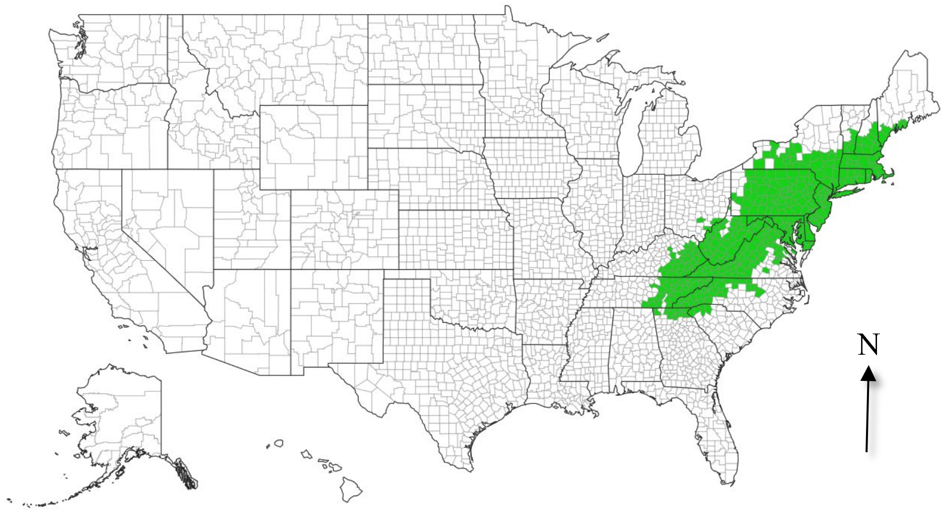


Figure 4-6. Range of HWA in the United States. EDDMapS. 2019. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available online at http://www.eddmaps.org/; last accessed June 14, 2019. Data based on public and citizen reporting of observations of the species.

Of the forest pathogen species known to occur near the AHTF, the ALB is the only species likely to have population level effects on the AHTF. The ALB is a generalist tree parasite; however, one of the preferred species of the ALB is sugar maple, the overwhelmingly dominant species in the forest canopies in the AHTF habitat. Infestation in the AHTF habitat by this species could remove the canopy species and dramatically decrease or potentially extirpate populations, especially with associated increases in other invasive understory or competitive native species that may then increase under higher light conditions. The ALB is currently only found in a few locations near Toronto, Canada, Chicago, Illinois, Worcester, Massachusetts, and New York, New York (Figure 4-7).

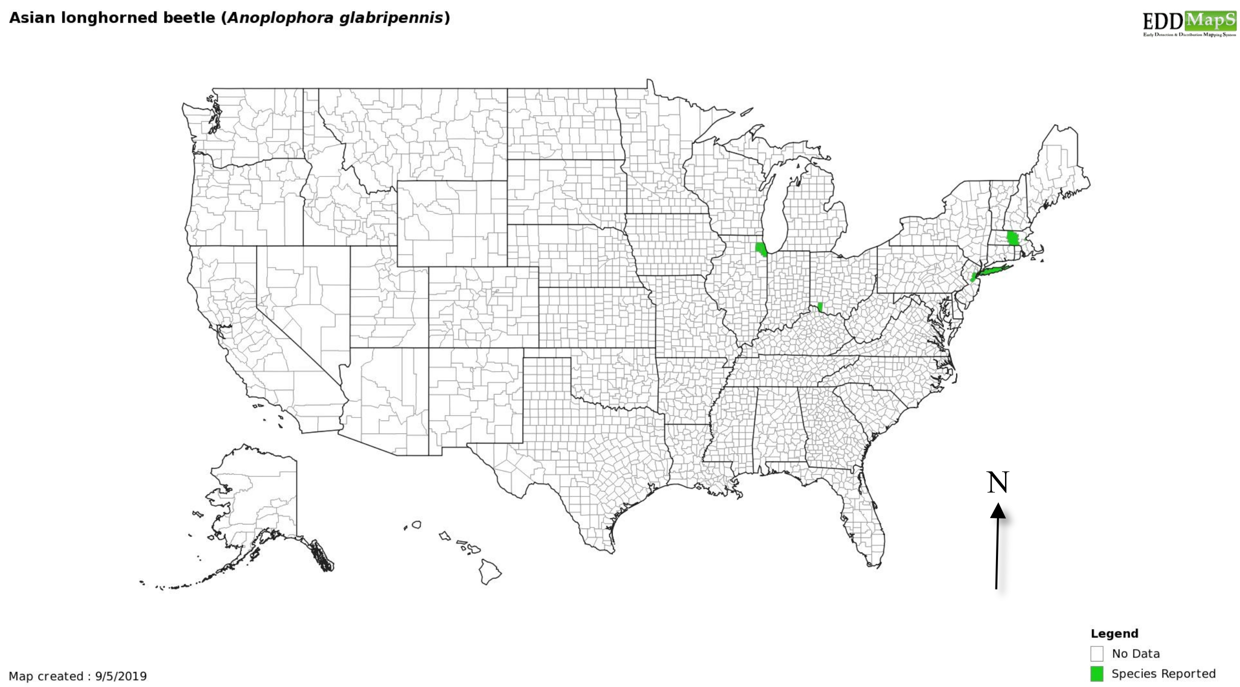


Figure 4-7. Range of ALB in the U.S. ALB is also known from one location in south-central Ontario. EDDMapS. 2019. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Online at http://www.eddmaps.org/; last accessed September 5, 2019. Data based on public and citizen reporting of observations of the species.

4.5 Climate Change

The AHTF is dependent on the cool, moist microclimates where it occurs and is, therefore, climatically sensitive to moisture stress brought on by drought and high temperatures (Testo and Watkins 2013, pp. 2265–2267). Despite being adapted to cool climatic conditions, the AHTF is likely sensitive to freezing temperatures either directly, through leaf tissue or root crown damage, or indirectly, through frost heaving (Cinquemani Kuehn and Leopold 1992, pp. 68–75; Kelsall et al. 2004, pp. 165–167). Decreases in the duration of snow on the ground that increase freeze damage or frost heaving and increases in drought that may occur as a result of climate change may cause populations of AHTF to decline. Snowpack depth was utilized as a proxy for number of days snowpack is present on the ground. We did not locate any information related to number of days on the ground for current trends or future projections; however, deeper snowpacks will likely be more persistent.

Changes in forest composition may be expected as climates shift. Fuytma (1980, pp. 85, 87) describes fossil pollen studies in northern Michigan that indicate that the northern hardwood forest preferred by AHTF, which replaced the coniferous systems where AHTF is not known to occur, may have only occurred in the past 10,000 to 5,000 years since the last glacial period. This is further supported by more extensive pollen studies across the Midwest finding that *Acer* spp. pollen arrived in northern Michigan between 8,000 to 7,000 years (Webb et al. 1983, p. 157).

4.5.1 Snowpack

There have been few quantitative studies of the impacts on critical biological processes of AHTF associated with the presence, depth, and duration of winter snow. The presence of a consistent seasonal snowpack can prevent freeze-thaw cycles and buffer perennial plant tissues from damage due to extreme winter soil temperatures and water stress associated with immobile frozen water (Brown and DeGaetano 2011, p. 947; Zuckerberg and Pauli 2018). Reductions in snow cover can decrease germination rates and establishment of early life stages partly due to the direct impacts of cold temperatures, but also due to the lack of spring moisture reserves during melting (Gornish et al. 2015, pp. 595–596). While the seasonal depth of snow in the Great Lakes Basin has decreased by 25 percent across the entire Great Lakes Basin in the 20th century (Suriano et al. 2019, entire), the Great Lakes Snowbelt has generally maintained consistent or increased slightly to moderately in lake-effect snow amounts (Baijnath-Rodino and Duguay 2018, entire). The extent and duration of lake ice on the Great Lakes are two of the principal factors controlling the amount of lake-effect snow. When large areas of the lakes are covered with ice, the moisture cycle that generates lake-effect snow systems is greatly diminished (Brown and Duguay 2010, p. 692). In New York, the frequency of lake-effect snows has generally increased since 1950 (Suriano and Leathers 2017, p. 4384), and the long-term trend for lake-effect snow fall has been increasing, largely due to increases in Great Lakes water temperatures and declining ice cover (Burnett et al. 2003, pp. 3539–3541) (Figure 4-8). More recent analyses of snowfall data for Lake Michigan have shown some evidence of a decrease in lake-effect snowfall from 2000 to 2005 (Bard and Kristovich 2012, pp. 2044–2055).

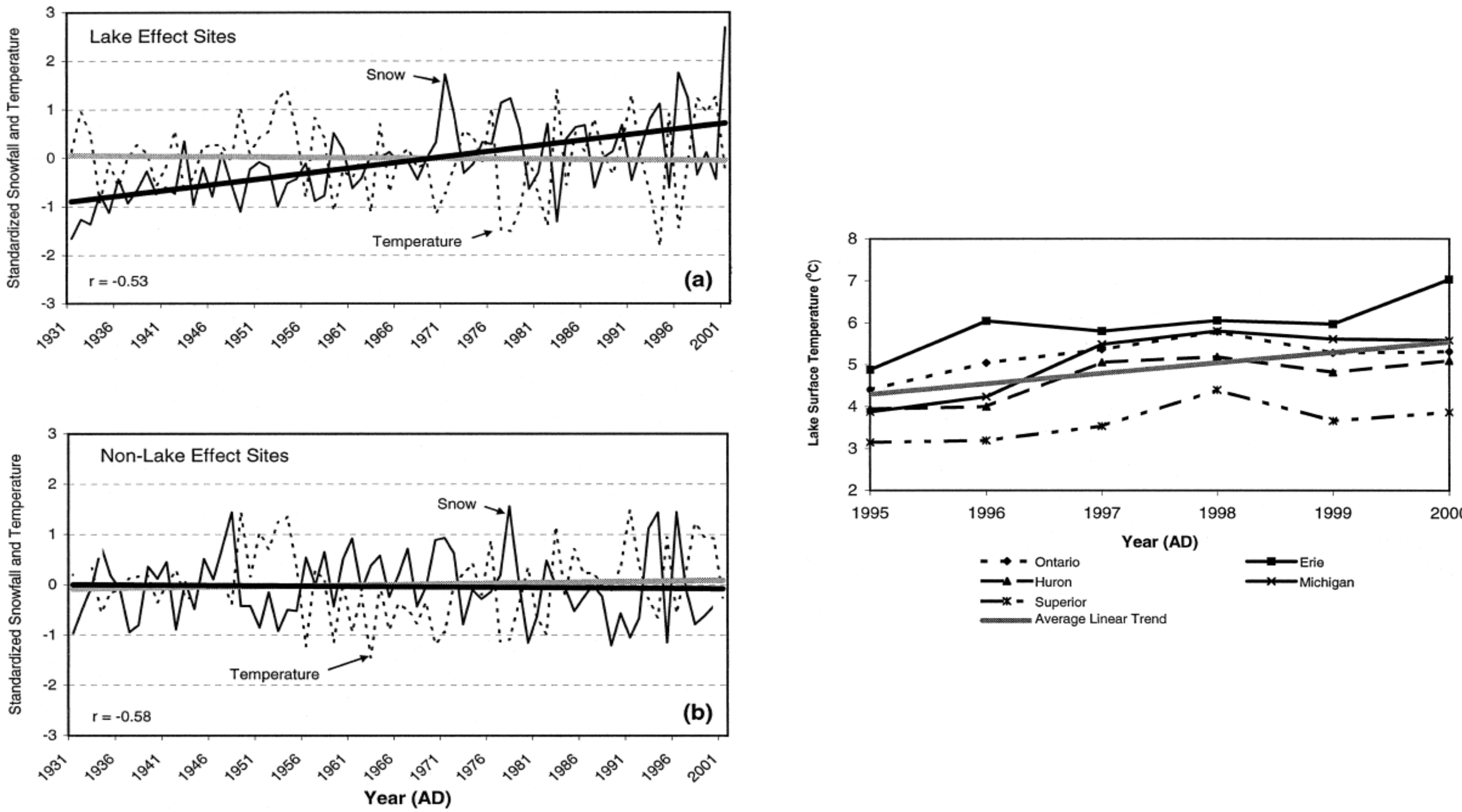


Figure 4-8. Trends in Great Lakes lake-effect snowfall and temperature at lake-effect and non-lake-effect locations (left) and trends in Great Lakes October - April average water surface temperatures (right). Figures from Burnet et al. (2003, pp. 3539–3540).

4.5.2 Drought

The Great Lakes Region during the 20th century has generally shown increases in mean temperature and total precipitation (GLISA 2019, entire). Since the 1950s, the average temperature in the Great Lakes Region has increased 2.3 °F (1.3 °C) and the total precipitation has increased by approximately 14 percent. Although total precipitation has increased, this has generally been due to an increase in severe storms and not necessarily representative of consistently high precipitation during the year.

Moisture availability is believed to be a major limiting factor in the micro-scale distribution of the AHTF. Regional drought, as measured by the Palmer Drought Severity Index, has been associated with historic declines in AHTF populations (Cinquemani Kuehn and Leopold 1993, pp. 68–75), and is significantly negatively correlated with population size of mature AHTF sporophytes (Kelsall et al. 2004, pp. 165–167). Testo and Watkins (2013, p. 2268) found that the gametophyte of the AHTF were significantly less tolerant to drought and desiccation relative to other fern species occurring in similar habitats. Cinquemani Kuehn and Leopold (1993, pp. 315–316) found that the majority of sporelings occurred on substrates covered in dense bryophyte mats, and postulated that this may be due to a tendency of bryophytes to maintain higher local moisture levels. The tendency of sporelings to be present predominantly on high moisture bryophyte mats, might be a result of the gametophyte's dependence on the presence of a thin film of water to allow motile sperm in the antheridia to travel to, and fertilize, an egg within the archegonia in order to produce a sporophyte (Page 2002, pp. 9–10). Once established, an AHTF may live for many years, having a small but positive carbon balance as long as the ecological conditions remain more or less unchanged, but the species is quite sensitive to habitat changes, and shifts to drier conditions are particularly detrimental (Lösch et al. 2007, p. 234).

4.6 Collection, Recreation, and Observer Impacts

At the time the species was listed, there was limited commercial trade of the AHTF material, which was believed to be of cultivated origin and not obtained from wild populations. The original source of this material was one of the New York populations that was destroyed in the early 1900s by quarry operations (S. Clements, New York Natural Heritage Program, pers. com. as reported in USFWS 2012, p. 15). Currently, there does not appear to be a commercial source for AHTF plants. Most of the populations in New York, Michigan, Alabama, and Tennessee are small and could not withstand any collecting for scientific purposes, for fern enthusiasts, or for other reasons. Inappropriate collecting remains a threat to these populations (USFWS 2012, p. 15). The larger Ontario populations have withstood, apparently without ill effects, low levels of collecting for some time (USFWS 2012, p. 15). Collection likely led to declines at the one extant Tennessee population (McGilliard 1936, p. 120) and the recently extirpated population in Michigan (USFWS 2012, p. 9).

Plants of the AHTF can be impacted directly during recreational activities, collection for scientific or commercial purposes, or during surveys/research. Many populations of the AHTF are in close proximity to trails in state parks in New York, recreational areas and along the Bruce Trail in Canada, and in the vicinity of the North Country Trail in Michigan. Several populations have been noted to be affected by recreational access or recreational development including trail development in Chittenango Falls, New York (Stebbins 1935, p. 106). All of the populations in the Appalachian Karst unit and one location in Ontario have been impacted by spelunking in the sinkholes and caves where the AHTF occurs. These activities likely contributed to the decline or extirpation of 3 of the 5 recorded populations in southern portion of the range (A. Cressler, USGS, pers. com.). One population in Ontario is noted as being impacted by recreational climbing activities (COSEWIC 2016, p. 26).

Populations of the AHTF in the U.S. are routinely surveyed and monitored, and the steep rocky slopes that the species occurs on can be difficult to safely traverse by the surveyors, resulting in potential impacts to the plants. In order to limit these impacts, a 5-year survey cycle has been established to limit observer impacts to the populations.

4.7 Conservation Actions

The AHTF is listed as Endangered in Michigan and Tennessee and Threatened in New York. Alabama does not have a State law equivalent to the ESA, so species do not have regulatory protection as State listed endangered or threatened species. In Michigan, it is unlawful to take a State listed plant species without a permit (Part 365 of PA 451 § 324.36505, 1994 Michigan Natural Resources and Environmental Protection Act); however, in Tennessee and New York, collection or destruction of listed plant species is allowed without a permit on private lands with the permission of the landowner. The AHTF is listed as At-Risk in Canada and in Ontario with a status of Species of Concern.

Protection of known populations was the primary recovery goal outlined by the Service in the Recovery Plan (USFWS 1993, pp. 10–11). In this SSA, we also consider the protection status of the populations to be of considerable importance in determining the future condition of the species (Section 5). Populations on protected lands are not threatened by development and quarrying, at least directly, as these activities are generally precluded on protected properties. However, the degree of protection afforded by a particular manager varies with respect to threats other than quarrying and development. Some protected areas are managed as preserves, where no anthropogenic disturbances are allowed, while others may allow extensive recreational activities, or even logging. The available resources at each protected area to manage public use and potentially mitigate invasive species also varies. In this SSA, we considered a population "Protected" if the ownership of the population precluded activities that tend to extirpate populations and habitat entirely, activities such as quarrying and development. In order to account for other impacts that may occur, we considered some Protected populations, where they are precluded from being logged and may have staff available to limit recreation and invasive species impacts, to be "Managed." When some of the population occurred on protected lands, we considered the population protection status as "Partial."

There are currently 59 Protected populations (41 percent) of AHTF in the U.S. and Canada (Appendix A). An additional 14 populations in Ontario (10 percent) have Partial protection. Of the Protected populations, 47 (80 percent of all Protected populations and 33 percent of all populations) are both Protected and Managed. In Canada, 34 populations are Protected and 9 are not Managed, while 62 populations are not Protected. In the U.S., 25 populations are Protected and all except 3 are Managed, while 7 populations are unprotected. Michigan, Alabama, and Tennessee all have one unprotected population, while New York has 4 unprotected populations. Approximately, 62,000 plants (51 percent) are Protected with approximately 98 percent of the Protected plants also Managed. Approximately, 34,500 plants (28 percent) are partially protected, as several large populations in Ontario are extensive and not contained within parcels owned by a single landowner.

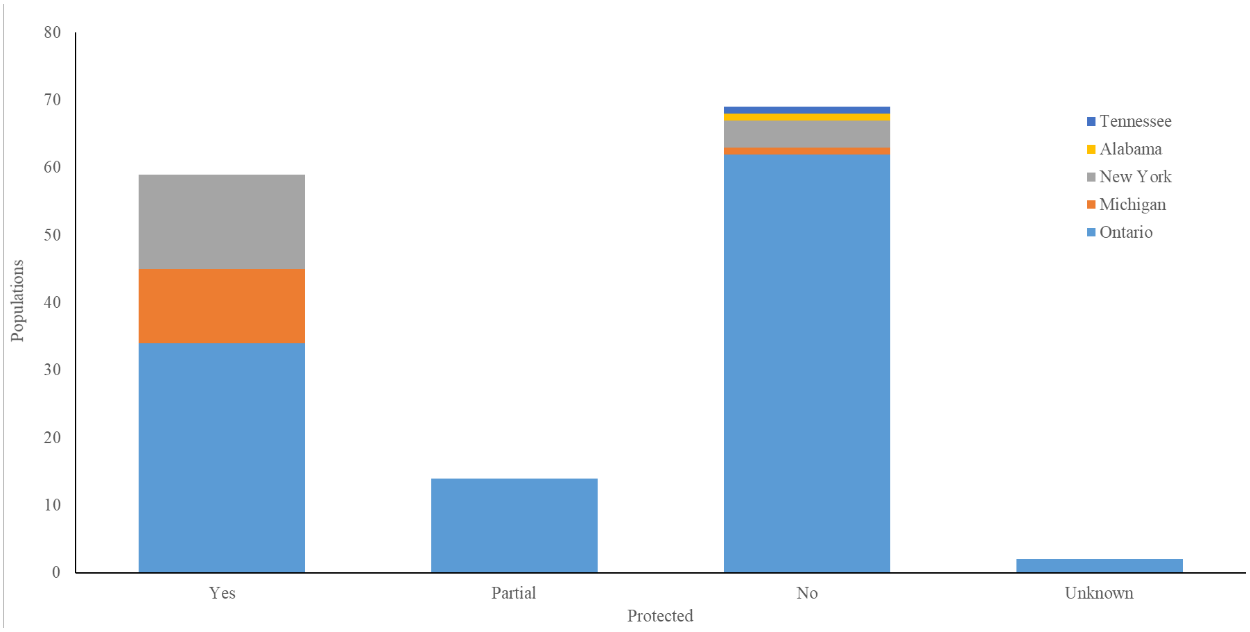


Figure 4-9. Number of populations of the AHTF that are protected by State/Province. Protected means that the ownership of the population precluded activities that tend to extirpate populations and habitat entirely, activities such as quarrying and development.

In Canada, the AHTF is located in the Niagara Escarpment Biosphere Reserve (Figure 4-10). The 2016 COSEWIC Report (COSEWIC 2016, p. 29) describes the protected status of the AHTF in Ontario, indicating that the habitat of Special Concern species and cliffs and talus slopes are considered significant wildlife habitat. Some habitats of AHTF are also considered significant woodland, depending on the size of the habitat and its geographic location. In addition, most privately owned lands with AHTF are designated as Areas of Natural and Scientific Interest (ANSI) (Riley et al. 1996, entire). The natural heritage section of the Ontario Provincial Policy Statement requires there be no development or site alteration in significant wildlife habitat or in ANSI designations unless it has been demonstrated that there will be no negative impacts to the natural features or their ecological functions. Many private lands in Ontario fall within the Escarpment Natural Area or Escarpment Protection Area land use designations of the Niagara Escarpment Plan (Niagara Escarpment Commission 2017, entire). Within these designations, certain types of development on private lands are restricted. The Niagara Escarpment Plan also contains policies requiring that impacts to the habitat of Special Concern species be minimized. These designations do not necessarily prevent a landowner from making many types of site alterations that do not require applications or permits. Thus, clear cutting, on-site road construction, and extraction of stone or aggregate for on-site private use may still occur on these lands. COSEWIC (2016, p. 29) notes that on occasion, the abundance of the AHTF in other parts of its range has been used to justify negative local impacts to the AHTF. In summary, approximately half of all populations and the majority of all plants in Ontario are protected. Protection for the AHTF on private lands exists but does not preclude the potential for impacts; however, the existing regulatory mechanisms are more protective than the ESA.

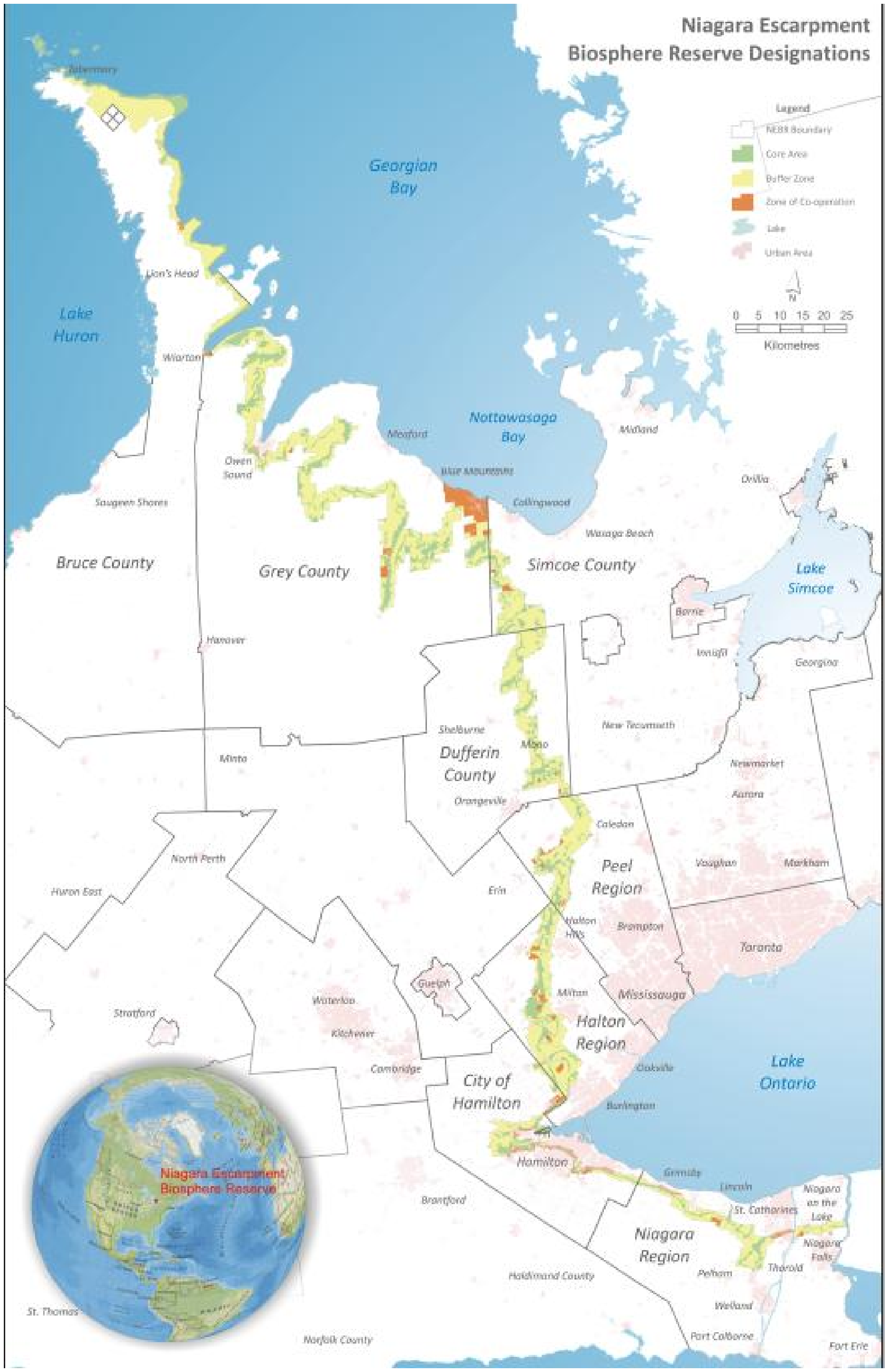


Figure 4-10. Map of the Niagara Escarpment Biosphere Reserve provided by the United Nations Educational, Scientific, and Cultural Organization. The Niagara Escarpment Plan Area is generally coincidental with the biosphere reserve designation.

In Michigan, the majority of the populations of the AHTF are located on U.S Department of Agriculture National Forest lands. The AHTF on these federal lands are protected under the guidance of a USFS Forest Plan (USFS 2006, entire). In the absence of ESA protections, the AHTF would fall under the list of Regional Forester Sensitive Species (RFSS), which includes guidelines for control of invasive species, surveys, and minimization of impacts to RFSS (M. Reuber, USFS, pers. com., 2018). The RFSS are addressed within the Forest Plan under the same section as ESA listed species. The ESA listed species are currently managed under a standard (which cannot be deviated from without modification of the Forest Plan) to protect all known ESA species that would preclude logging in the populations. The USFS regularly surveys for and mitigates potential impacts to the AHTF during its management activities. Recent decisions by the USFS have utilized a 200 m (660 ft) buffer around existing populations (73 FR 5497). The RFSS are managed under a guideline (which may be waived with justification) to avoid, minimize, or mitigate adverse impacts to these species. Removal of ESA protection for the AHTF would lower the current protection afforded to the species on USFS lands from a mandatory limitation of impacts to a less restrictive level that may allow some impacts to the ATHF to occur. The majority of the plants in Michigan are located on two preserves owned by the Michigan Nature Association. The Michigan Nature Association has a central focus on protection mandates with a mission tied to rare species, natural communities, and unique geologic features that would continue to protect the AHTF regardless of its status under the ESA (A. Bacon, MNA, pers. com. 2018).

In New York, the majority of populations occur on NYSOPRHP properties. The NYSOPRHP regularly monitors and controls invasive species in the vicinity of the AHTF populations both at their properties and at one site on New York State Department of Environmental Conservation (NYSDEC) lands. A propagation program funded by the Great Lakes Restoration Initiative (GLRI) and ESA Section 6 funding to the NYSDEC has been ongoing at SUNY-ESF since the early 2010s (D. Fernando, SUNY-ESF). While other propagation programs have been attempted in the past, none of these has been successful at either growing the AHTF or establishing the plants in the wild due to the specificity of the growing requirements of the AHTF and the need to slowly acclimatize propagated individuals over several years. The current effort resulted in the planting of 3 populations in 2015 that have been monitored over time and have apparently established at their respective locations (Serviss 2017, entire). This program is transitioning from a research effort to a management program for propagation and invasive species control that the NYSOPRHP will continue through GLRI funding. Plants from New York, Michigan, and Alabama are currently under propagation at both SUNY-ESF and by NYSOPRHP. Regeneration of invasive plants from robust seed banks in the habitats will likely continue for many years into the future, requiring intensive management by New York State Agencies, including the NYSOPRHP and the NYSDEC.

Figure 4-11. Propagated individuals of the AHTF at the State College of New York Environmental Science and Forestry.

Propagation of sporophytes through tissue culture has also been successful in a laboratory setting (Pence 2015, pp. 211–225). These plants originated from collection from the extirpated population in Alabama. It may be possible to reestablish this population using propagated plants as the location is on Service Refuge lands, where impacts due to recreational cave access may have been the primary cause of extirpation and can be limited by proper access management. The SUNY-ESF produced and NYSOPRHP currently has these plants that could be used for that restoration effort.

5 ANALYSIS OF FUTURE VIABILITY

In this SSA, we have defined the demographic and resource needs for AHTF viability and presented an analysis of the current condition of the species. Here, we provide an analysis of the future viability of the AHTF under two potential scenarios over two timeframes to incorporate potential uncertainty with future predictions. Based on the analysis of factors influencing the viability of the AHTF, we selected climate change and invasive species as the most important factors to evaluate into the future. These factors were selected as our review has shown that these two factors are most likely to impact the majority of populations and individuals across the species' range. The other factors considered are localized or would only occur at unprotected, generally small, populations and are not likely to be extensive across those populations based on historical trends across the species' range.

5.1 Scenario Development

5.1.1 Factors Not Considered Explicitly

In this analysis of future condition, we have not directly assessed the effects of all of the factors considered in Section 4 that may influence the future condition of the species. Documentation for many of the populations of the AHTF in Ontario is less detailed than for populations in the U.S. Our ability to accurately predict the potential impacts of certain stressors on the AHTF at a population-level in Ontario, where the majority of the populations and plants occur, is limited by the available information regarding these populations. We expect that impacts related to collection, recreation, and observer impacts will occur during the timeframe of our scenarios; however, we expect these impacts to be minor, and to have the greatest impact on very small populations. We expect that small populations with Low rank for resiliency will be the most impacted in our future scenarios. In particular, while populations with less than 100 individuals were ranked as Low for population resilience (Table 3-2), demographic data from New York, Michigan, and Alabama has shown that populations with long-term (greater than 10 years of data) with less than 10 to 20 individuals have a high risk of extirpation.

Impacts due to future development and quarrying are possible; however, we expect these impacts to affect only unprotected populations. Over 50 percent of the populations, encompassing approximately 80 percent of the plants, occur on protected lands, and only 9 High ranked populations occur on unprotected lands. Impacts from these activities should not affect the U.S. populations because nearly all populations are protected and the remainder of the populations occur in areas where development or quarrying is precluded by zoning or unlikely based on site conditions (i.e., steep slopes, proximity to residences). In Ontario, planning restrictions on alteration of habitat for Special Concern species controlled by the Niagara Escarpment Plan and in ANSI-designated sites limit widespread conversion of the AHTF habitats due to development and quarrying, even on private lands. We acknowledge that these policies do not have the regulatory authority that would be provided by more stringent endangered species laws. Even with these protections, development applications will likely be approved in the vicinity of the AHTF in Ontario with potentially large negative effects on the individuals at affected populations. While we expect reductions in some and potential loss of other populations due to these activities in Ontario, these will be limited in number and extent through existing conservation mandates. Therefore, we have not considered these activities further in our analysis.

Impacts due to logging are expected to occur and may result in population declines and potential extirpations at most unprotected populations across the species range. As addressed above, the majority of the AHTF populations and a considerable majority of the plants occur on protected lands, so we do not expect logging to have a significant overall impact on the viability of the AHTF. Additionally, whether a particular population is logged or not is relatively random from an analysis perspective, and incorporating this aspect of the future condition would add considerable complexity to our analysis. We have attempted to address the largest, rangewide factors influencing the AHTF below, but our results do not reflect potential declines and extirpations due to logging in the next 50 or more years. Approximately 20 populations in Ontario have been negatively affected by logging in the last 50 years, and if these trends continue, we could expect that a similar number may be impacted by logging over a similar timeframe. Our analysis is likely optimistic for populations occurring on private lands where these impacts may occur.

5.1.2 Climate Models and Timeframes

The climate change projections used in this SSA report are based on Representative Concentration Pathway (RCP) scenarios. The RCPs are the current set of scenarios used for generating projections of climate change. There are four RCPs selected to be representative of the range of theoretically possible atmospheric conditions, and the pathways along which they would occur, that could exist by the year 2100. The RCPs are based on more than 100 scenarios in the scientific literature at the time the RCPs were developed (van Vuuren et al. 2011, p. 13). For information about the RCP scenarios, please see van Vuuren et al. (2011, entire) or Collins et al. (2013, pp. 1044–1047).

The climate change projections based on RCP 4.5 and RCP 8.5, represent the “medium-low” and “highest” scenarios, respectively. We did not use the “lowest” scenario, RCP 2.6, because it is considered unlikely to occur (e.g., Foden et al. 2019, p. 19). The RCP 4.5 and RCP 8.5 scenarios are commonly used together in the scientific community, and these scenarios were selected as the basis of projections for assessing climate change impacts, vulnerability, and adaptation responses in the development of the Fourth National Climate Assessments (U.S. Global Change Research Program 2015, entire). By 2100, the atmospheric conditions under RCP 4.5 are associated with a projected global average temperature that is 2.4 ± 0.5 °C higher compared to 1850-1900, and the conditions under RCP 8.5 by 2100 are associated with a projected global average temperature that is 4.3 °C ± 0.7 °C higher compared to 1850-1900 (Collins et al. 2013, pp. 1055–1056).

5.1.3 Snowpack

Several global climate models that attempt to forecast future changes in future trends in snowpack have been ineffective at developing predictions in the snowbelt areas of the Great Lakes, including the Niagara Escarpment, where regional, downscaled climate models are needed (Janoski et al. 2018, p. 9052). Currently available methods used to model snow density and snow depth may not adequately represent future conditions in lake-effect regions where snow density is often lower (Roebber et al. 2003, p. 264). Generally, the frequency of snow cover is expected to decline by 20 to 50 percent in the 21st century along the Niagara Escarpment and result in a shorter winter period with more snow free days (Ning and Bradley 2015, p. 4). The regional Great Lakes snowfall trends are projected to decrease overall with shorter snow-covered periods and increasing temperature under low and high-emission future climate scenarios (Byun and Hamlet 2018, p. e543; Ning and Bradley 2015, p. 4; Suriano and Leathers 2016, p. 2205). Longer term models suggest that precipitation may initially increase and then decrease toward the end of the century, although the degree of uncertainty in RCP 4.5 and RCP 8.5 models is higher where the AHTF occurs than in other regions of the Great Lakes. Under the RCP-emission model scenarios the length of winter is expected to decrease and snow depth is predicted to decrease and largely disappear later in the 21st century (Chin et al. 2018, pp. 47–53).

However, in models specifically accounting for the effect of lake-effect snowfall, the Great Lakes snowbelt is projected to either maintain or slightly increase lake-effect snows in the next 30 to 50 years, and then snowfall is projected to strongly decline further into the 21st century (Suriano and Leathers 2016, p. 2205) (Figure 5-1). Other regionally down-scaled snowfall models have predicted moderate declines in snowfall and snow depth early in the 21st century and corroborate significant later declines, especially for snow depth with warming temperatures (Suriano and Leathers 2016, p. 6539). Lake-effect snows and snow covered periods are projected to decrease in duration from the current period of November to April to a predicted period spanning the months of January to March (Notaro et al. 2014a, pp. 1676, 1680). As the regional temperature warms, the ratio of snowfall to total precipitation will decline, and the Great Lakes can expect to receive higher precipitation with less amounts of total snowfall over time (Notaro et al. 2014b, p. 6545; Suriano and Leathers 2016, p. 2205) (Table 5-1).

Table 5-1. Trend, correlation, and significance of snowfall for likely climate scenarios and for specific periods. SWE = snow water equivalent. LIB = lake-effect snowbelt. Table from Suriano and Leathers (2016, p. 2205). Whole region 2-m temperature analyzed in Kelvin. Starting and initializing values for percent calculations are found in (Suriano and Leathers 2016, entire).

Variable	Scenario	Time period	Trend	R^2 value	p value
Whole region SWE	RCP 4.5	-	20% decline	0.37	<0.0001*
Whole region SWE	RCP 8.5	-	45% decline	0.75	<0.0001*
LIB SWE	RCP 4.5	-	20% decline	0.33	<0.0001*
LIB SWE	RCP 4.5	2006–2050	14% decline	0.23	0.0011*
LIB SWE	RCP 8.5	-	45% decline	0.73	<0.0001*
LIB SWE	RCP 8.5	2006–2030	10% increase	0.13	0.0870
LIB SWE	RCP 8.5	2031–2100	43% decline	0.72	<0.0001*
Pure LI SWE	RCP 4.5	-	19% decline	0.03	0.1074
Pure LI SWE	RCP 8.5	-	44% decline	0.16	<0.0001*
Whole region 2-m temperature	RCP 4.5	-	1% increase	0.78	<0.0001*
Whole region 2-m temperature	RCP 8.5	-	2% increase	0.94	<0.0001*
LIB total precipitation	RCP 4.5	-	11% increase	0.24	<0.0001*
LIB total precipitation	RCP 8.5		11% increase	0.26	<0.0001*
LIB snow–precipitation ratio	RCP 4.5	-	29% decrease	0.50	<0.0001*
LIB snow–precipitation ratio	RCP 8.5	-	51% decrease	0.77	<0.0001*

A standalone hyphen (-) within time period denotes the entire period of record (2006–2100), while an asterisk (*) denotes significance at the 99% confidence level. The shaded rows distinguish the RCP 4.5 scenario.

Available data indicate that the AHTF will likely have additional or similar lake-effect snows in the Great Lakes Snowbelt in the next 30-50 years; however, the fundamental issue with likely projections of climate change will be the transition from snow with warming temperatures and the rate at which snowpack disappears in relation to winter minimum temperatures. If late 21st century minimum temperatures are still cold enough to adversely affect populations lacking available snow cover, populations may decline. Bremer and Jongejans (2009, p. 221) found that in EHTF in Amsterdam, long-term demographic data showed that frost damage negatively impacted fronds; however, they postulated that warmer winters resulting from climate change would improve the viability of these populations as the populations appear to be resilient to short-term losses from frost damage.

Byun and Hamlet (2018, pp. e545–e546) indicated that late 20th century extreme cold days (minimum temperature less than 5 °F [-15 °C]) varied from 10 to 20 days in New York, 20-30 days in Ontario, and 30 to 40 days in Michigan. Under RCP 8.5, they predict that the number of extreme cold days will decline to 0 to 5 in New York and 5 to 10 in Ontario and Michigan by the later 21st century. Areas downwind of Lake Superior, including the populations in Michigan, are predicted to maintain colder minimum temperatures, but also maintain higher snow depths, through the late 21st century than in other portions of the species range in Ontario and New York (Notaro et al. 2014a, p. 1681). We expect populations in Michigan to maintain a High condition for freeze/thaw buffer over time.

In Ontario and New York, potential frost damage may occur during snow-free periods. Due to the predicted increase in winter minimum temperatures with concomitant losses in winter snowpack, we predict that populations in New York will experience some losses during critical winter periods during the 50+ year timeframe under RCP 4.5 and in the 30-50 year timeframe for RCP 8.5 and will have a Medium rank for this factor. In RCP 8.5, the eventual reduction of the number of extreme cold nights would limit potential impacts and return the rank to High after 50+ years.

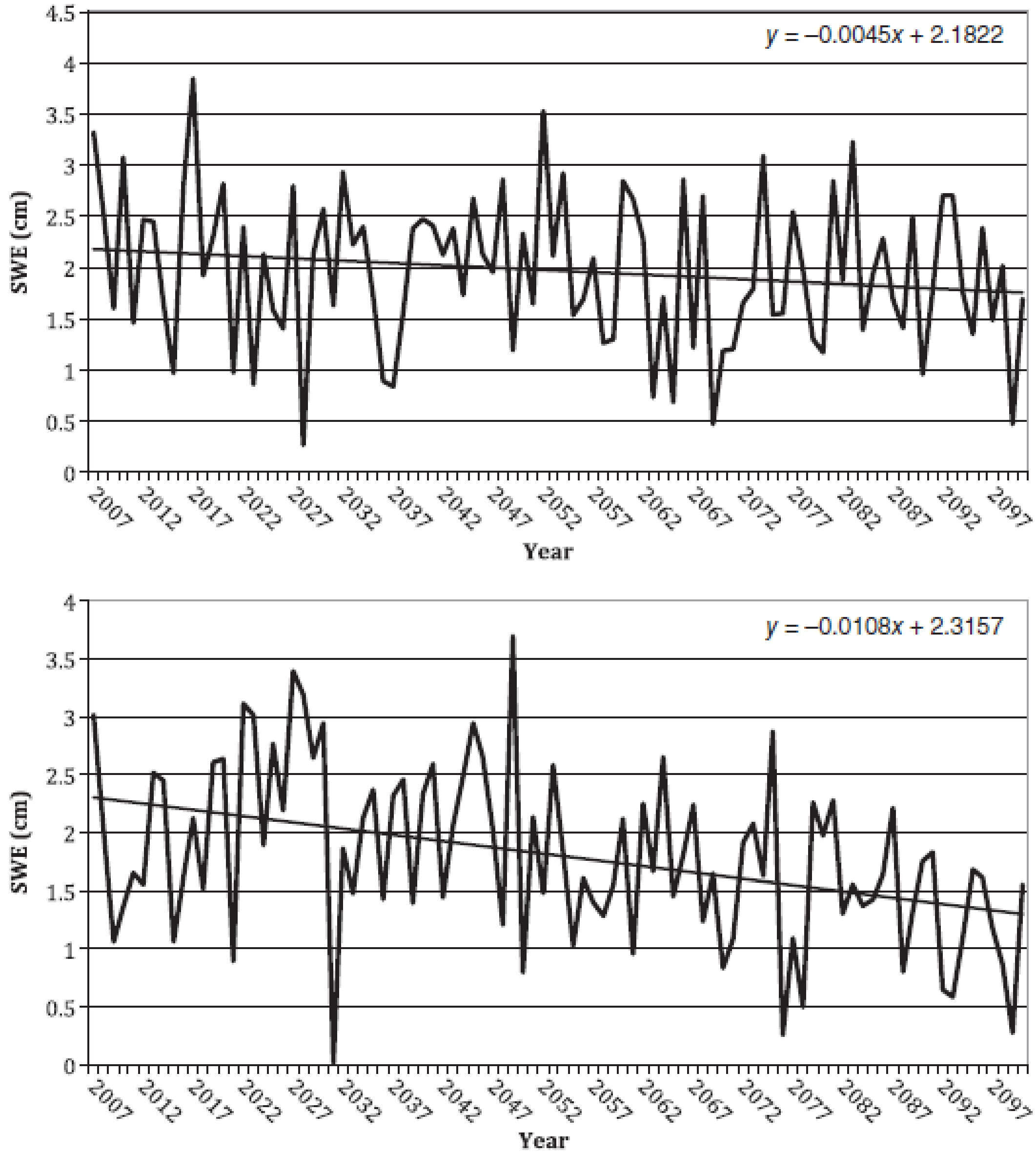


Figure 5-1. Mean of an ensemble of seven models of purely lake-effect seasonal snow water equivalent (SWE, i.e., snowfall) for RCP 4.5 (top) and RCP 8.5 (bottom) likely climate scenarios in the eastern Great Lakes region. Figures from Suriano and Leathers (2016, p. 2205). These results were generated from coarse-scale global climate models.

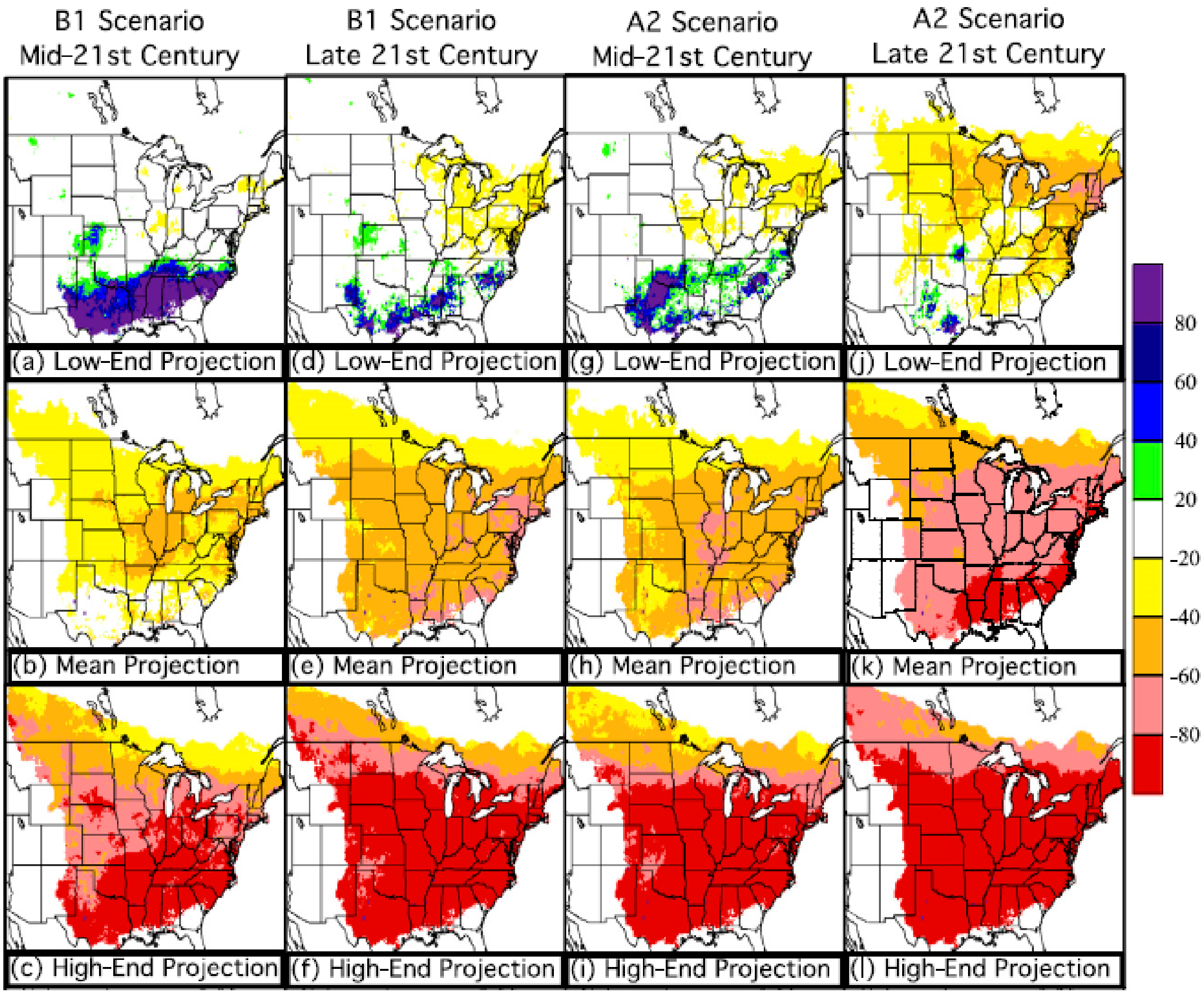


Figure 5-2. Percent change in predicted November through April mean snow depth (cm) for low emission (B1) and high emission (A2) scenarios from the late 20th century. Figures from Notaro et al. (Notaro et al. 2014b, p. 6539). These results were generated from a regionally specific dataset of dynamically downscaled climate data.

5.1.4 Drought

Future predictions of drought under low and high-emission climate scenarios suggest that a warming climate and increased moisture stress will be an increasing threat in the Great Lakes Region. Byun and Hamlet (2018, p. e540) evaluated seasonal changes under RCP 8.5 and found that summer precipitation in the months of June, July, and August may remain consistent or decline slightly by the later part of the 21st century, with wider variation in precipitation amounts. Lower precipitation in drier years coupled with a projected increase of approximately 11 °F (6 °C) in annual mean temperature by 2100, are expected to place a higher evaporative stress on the AHTF and potential for drought conditions during these months (Figure 5-3).

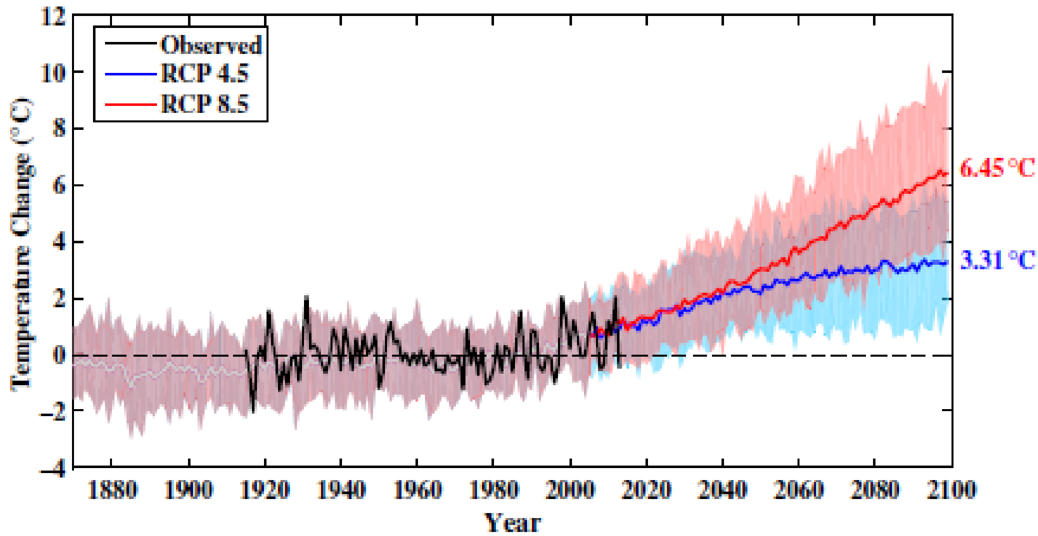


Figure 5-3. Trajectory of annual mean temperature change over the Great Lakes Region relative to the annual mean temperature for the late 20th century. Shaded bounds represent the 95 percent confidence interval from the ensemble mean of 31 global climate models. Figure from Byun and Hamlet (2018, p. e538).

The models in Byun and Hamlet (2018, p. e540) lack the inclusion of lake-effect precipitation, which also occurs during warmer months. The additional precipitation from lake-effect rains (Notaro et al. 2014a, p. 1669), may help alleviate potential drought stresses in the Great Lakes Snowbelt populations, depending on their magnitude in relation to evapotranspirative stress. It is unknown to what degree the cool microsite conditions will buffer populations from temperature increases, but we expect micro-site buffering will be highest at the southern sinkhole sites. We expect ranks for moisture to decline under increased drought conditions when predicted, resulting in a drop from High to Medium, or Medium to Low, from current condition. Byun and Hamlet (2018, p. e547) did not predict any strong gradients across the northern portion of the range regarding future moisture conditions, so we have predicted changes equally across the northern portion of the range.

5.1.5 Invasive species

We chose to include European swallowwort and the ALB as two invasive species in future scenarios for the AHTF. These two species were chosen because they: 1) are already present at or in areas near to current AHTF populations; 2) are expected to cause population level impacts to the AHTF when present; and 3) are reasonably certain to occur within the range of the AHTF within the period of our future scenarios (Section 4.4).

European swallowwort is hypothesized to be climate-limited with lower mean winter temperature limits from 12 to 33 °F (-11 to 0.7 °C). Future climate models project that European swallowwort climate suitability will move north, potentially out of the range of the New York populations and likely be more centered on the Canadian populations after approximately 2050 (Figure 5-4). DiTommaso et al. (2005, p. 260) and Kricsfalusy and Miller (2010, pp. 33–34) both concluded that European swallowwort has rapidly spread across Ontario in the past 50 years and is likely to expand exponentially in Ontario in the foreseeable future.

The ALB is known to be restricted to cold hardiness zones that span from Mexico to southern Canada, and generation time (i.e., population growth rate) is closely linked to warmer temperatures (Kappel et al. 2017, p. 2001). Currently, the northern range of the AHTF has cold enough average temperatures to limit potential growth rates of the ALB (Figure 5-5). However, this portion of the range has the highest at risk forest stands preferred by the ALB (Figure 5-6), including areas in New York, Ontario, and Michigan where the AHTF occurs. The ALB has currently established infestations near the Ontario populations and in downstate New York and central Massachusetts that we expect will spread with changing climate and over time.

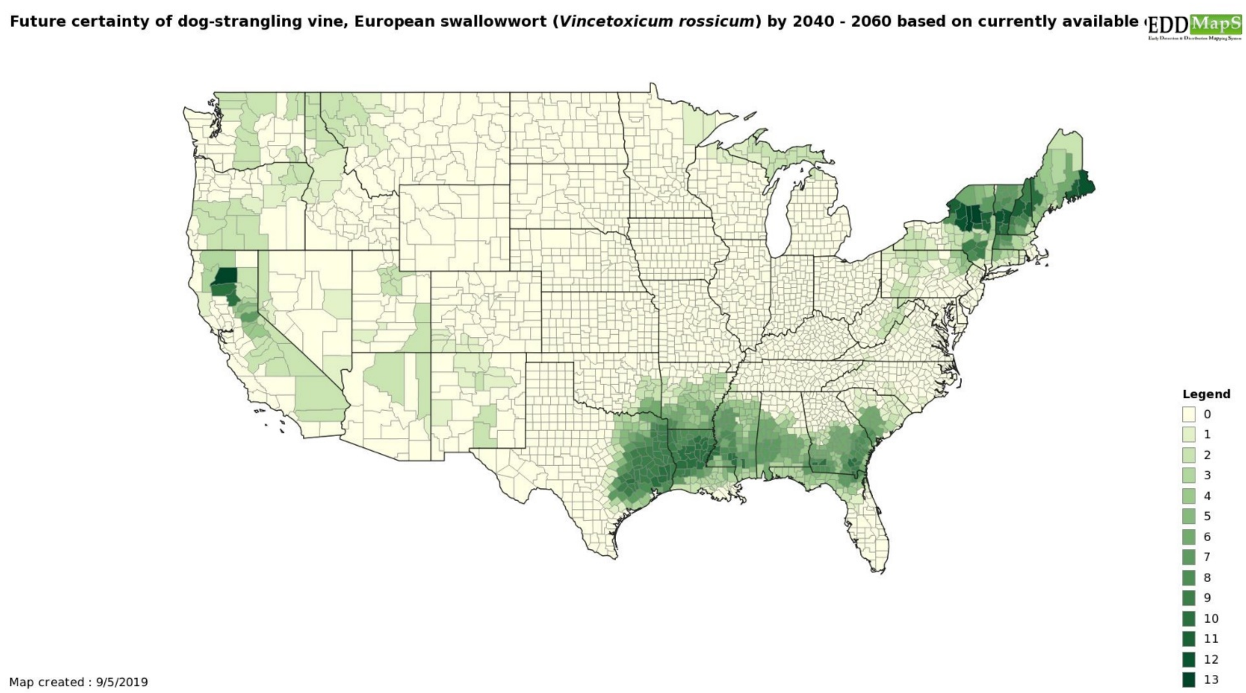


Figure 5-4. Future certainty of European swallowwort by 2040-2060 based on 13 model runs (scale likely occurrence in number of models) of future climate scenarios. Note the highest likelihood of occurrence has shifted out of Onondaga and Madison Counties, where the AHTF occurs. EDDMapS. 2019. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available online at http://www.eddmaps.org/; last accessed September 5, 2019.

Hunt et al. (2006, pp. 35–42) evaluated the potential spread of the ALB in Canada, utilizing various climate models to determine how increases in average temperatures would shift the potential range and ability for the ALB to complete its life cycle in 1 year (i.e., high growth rate). They found that under all of the low to high-emission scenarios examined, the ALB would likely be able to complete its life cycle in 1 year across the range of the AHTF by 2080. In the higher emission scenarios, this occurred by 2020 or 2050. Hunt et al. (2006, p. 35) note that their estimates of degree-day requirements for single year reproduction did not match well with actual data from near Toronto at the time. Based on the refined estimates in Kappel et al. (2017, p. 2001), it is clear that their starting estimates of range were biased higher, but the relative shift over time is likely representative of the time lags associated with the change in potential range.

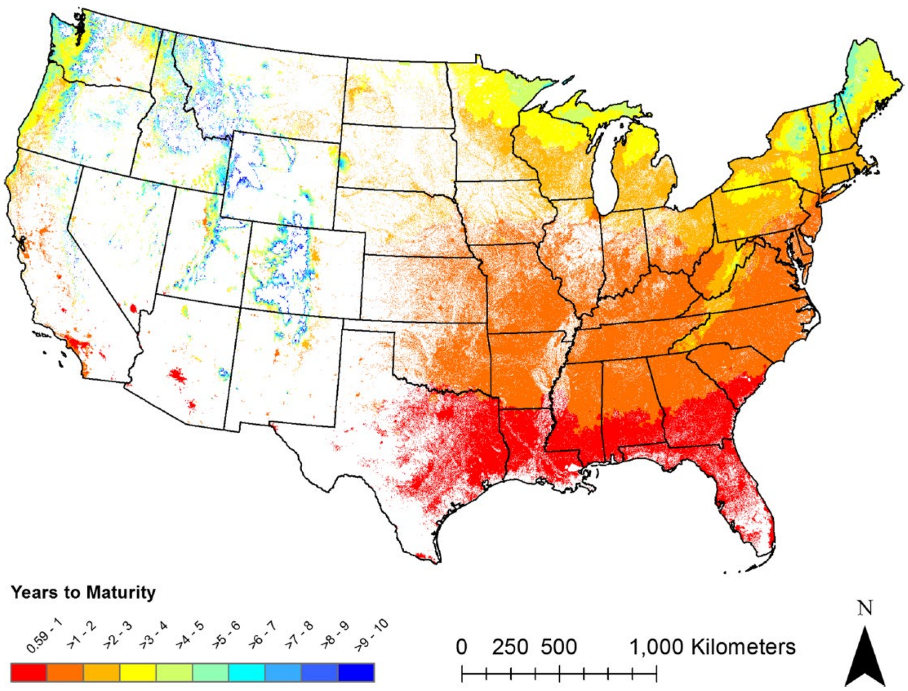


Figure 5-5. Number of years to maturity (i.e., length of reproductive cycle) for the ALB in the U.S. Areas where the AHTF occur in New York and likely in the southern part of Ontario are 2 to 3 years, while the northern portion of Ontario and Michigan are 3 to 6 years. Figure from Kappel et al. (2017, p. 2007).

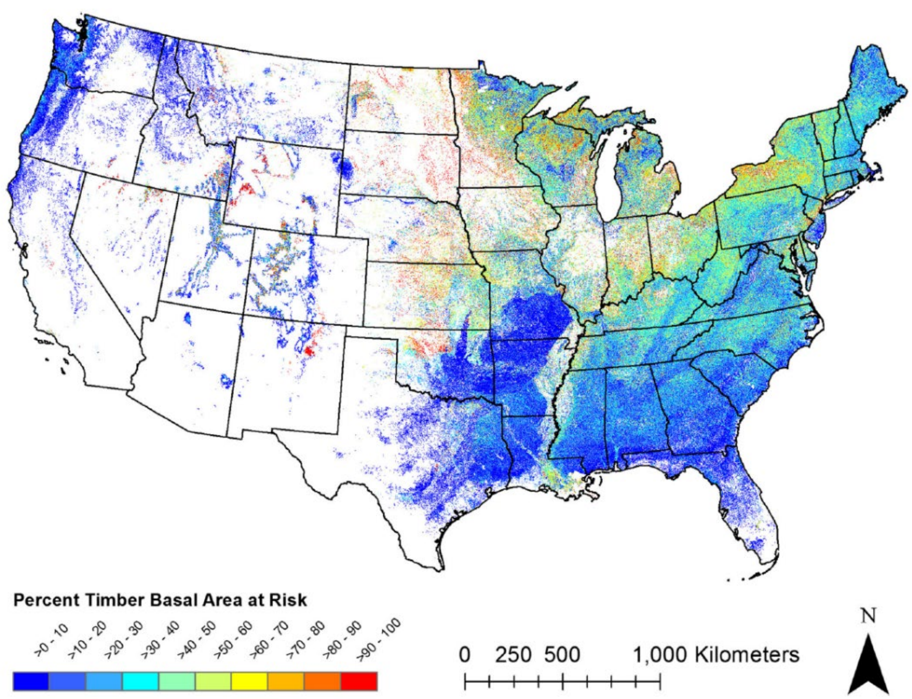


Figure 5-6. The percent timber basal area at risk to the ALB. Note that some of the highest areas of risk occur along the Niagara and Onondaga Escarpments in New York with localized areas of risk near the Michigan populations of the AHTF. Figure from Kappel et al. (2017, p. 2009).

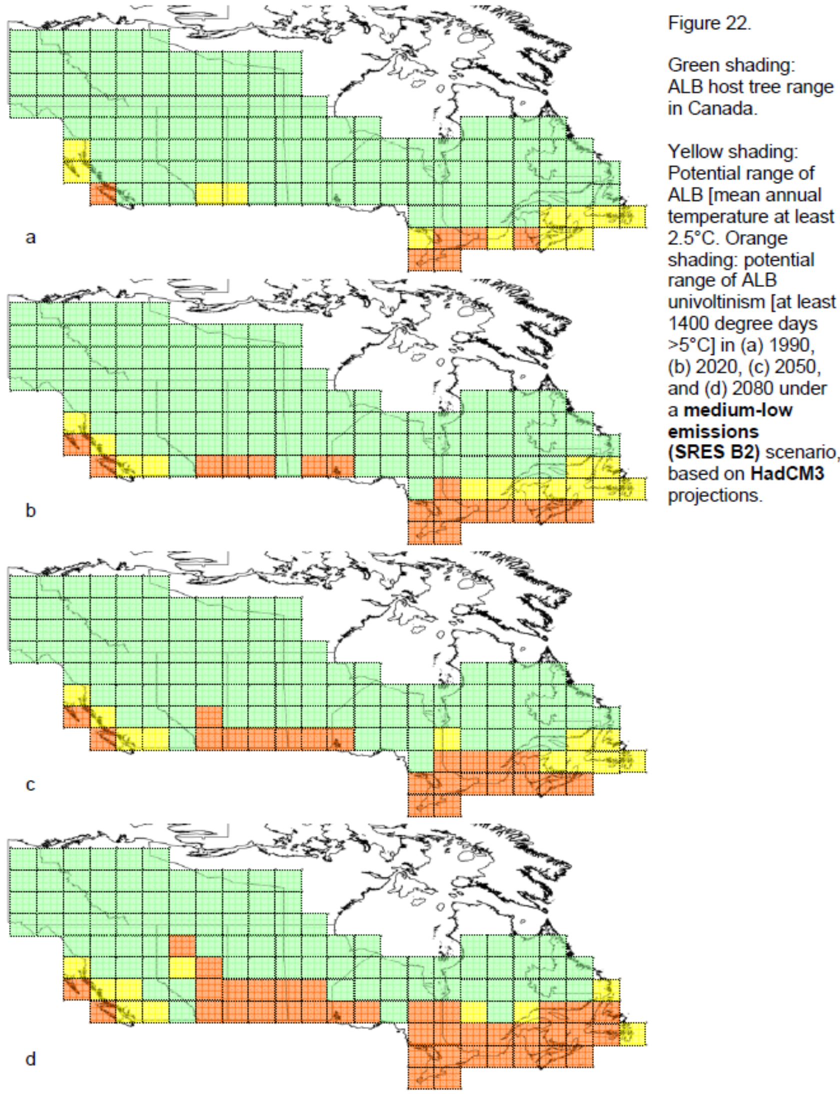


Figure 5-7. The potential spread of suitable (yellow) and 1-year life cycle (orange) range for the ALB in Canada under a medium-low emission scenario. Figure from Hunt et al. (Hunt et al. 2006, p. 38).

5.1.6 Scenarios and Assumptions

We selected two timeframes for analysis in this SSA based on our understanding of the factors influencing the AHTF, the expected future change of these factors as discussed above, and the expected species response to these changes. The two scenarios in this SSA are broken into 30 to 50 year and 50+ year timeframes. Regional climate trends are generally broken into middle and later 21st-century timeframes. Additionally, for the AHTF, the available regional climate models (Chin et al. 2018, pp. 47–53; Notaro et al. 2014b, p. 6545; Suriano and Leathers 2016, p. 2205) show distinct differences between the middle and latter periods of the 21st century. As climate models generally inform most future predictions of invasive species spread, these timeframes are additionally appropriate for our consideration of invasive species. The two scenarios considered for assessing future viability are outlined in Table 5-2. The ALB was added to Scenario 2 as this species is predicted to spread primarily under RCP 8.5.

Table 5-2. Scenarios assessing future viability.

	Climate Model	Invasive Species
Scenario 1	RCP 4.5	Spread of European swallowwort
Scenario 2	RCP 8.5	Spread of European swallowwort and ALB

In order to predict the future viability of the AHTF under our two scenarios, this SSA assumes a variety of changes in both the factors influencing the species, the demographics of the species, and the response of the habitat factors incorporated into our analysis as described in Table 5-4.

We utilized the current condition of the AHTF as outlined in Appendix B as the starting point for our scenarios. In this analysis, only populations that were ranked for current condition or Extirpated were included. Historical and Unknown populations could not be assessed for current condition, and therefore, were not assessed for future condition. Our future scenarios included 139 populations (117 ranked and 22 currently extirpated). In order to forecast changes to the AHTF, we evaluated the changes in each factor under each scenario based on our review of the factors influencing the species, including conservation actions addressing invasive species impacts (Section 4), and our review of the available information regarding future changes of these factors in this section (Change in Factor); predicted the effects to the AHTF (Effect on the AHTF); and then, utilized the definitions for rankings of factors considered for current condition in Table 3-2 to determine the change in ranking for these factors in our future condition (Analysis) (Table 5-4).

We have provided a summary of the expected changes by scenario and timeframe in Table 5-3. All calculations were performed identically to those for Current Condition in Section 3.2.2, except that Abundance and Trend were given at weight of 2.0 instead of 3.0 when compared to the other factors considered and in Scenario 2, all Light ranks influenced by the ALB were given additional weight (i.e., weight of 2.0). This reflects our uncertainty about what size and trend populations of the AHTF will be in the future. The current condition is considered less informative in future scenarios, although still important, to our overall calculation of future condition. Additionally, in Scenario 2, the impacts of the ALB and canopy loss are likely to concomitantly affect other factors including encroachment of invasive species and moisture stress, so the impacts of the ALB were given additional weight in our analysis.

While we predict future changes in condition for populations in the northern portion of the species' range, we currently have no information to suggest that the effects of the factors, other than drought, considered in this analysis will occur in the populations in the southern portion of the range. The European swallowwort and ALB do not currently occur in the southern portion of the range and are not expected to spread to or impact them. Additionally, these populations are also likely buffered from potential changes in freeze/thaw impacts due to their partially subterranean locations and current lack of association with areas of heavy snowpack.

Table 5-3. Summary of future condition scenario predictions for two scenarios for populations of the AHTF at 30 to 50 and 50+ years.

Scenario		30 to 50 Years				50+ Years			
	State/ Province	Snowpack (Freeze/Thaw Buffer)	Drought (Moisture)	European Swallowwort (Substrate)	ALB (Light)	Snowpack (Freeze/Thaw Buffer)	Drought (Moisture)	European Swallowwort (Substrate)	ALB (Light)
Scenario 1: RCP 4.5 and European Swallowwort	Ontario	No Change	No Change	All Managed → Medium All Unmanaged → Low		Medium	All High → Medium All Medium → Low All pops. <10 extirpated	All Managed → Medium All Unmanaged → Low	
	Michigan	No Change	No Change	No Change		No Change		No Change	
	New York	No Change	No Change	All Managed → Medium All Unmanaged → Low		Medium		All Managed → Medium All Unmanaged → Low	
	TN/AL	No Change	No Change	No Change		No Change	All <10 extirpated	No Change	
Scenario 2: RCP 8.5, European Swallowwort and ALB	Ontario	All Medium	All High → Medium All Medium → Low All <10 extirpated	All Managed → Medium All Unmanaged → Low	All Low	All Return High	All Low All <20 extirpated	All Managed → Medium All Unmanaged → Low	All Low Weight 2.0
	Michigan	No Change		No Change	No Change	No Change		No Change	No Change
	New York	All Medium		All Managed → Medium All Unmanaged → Low	No Change	All Return High		All High	All Low Weight 2.0
	TN/AL	No Change	All <10 extirpated	No Change	No Change	No Change	All <20 extirpated	No Change	No Change

Table 5-4. Assumptions and predictions of factors influencing the AHTF in the future.

Factors	Change in Factor	Effect on the AHTF	Analysis (see Table 3-2)
Climate Change: Snowpack (Section 4.5.1)	• Under RCP 4.5, we expect precipitation to increase and snowpack to remain consistent or increase slightly in the next 30-50 years with moderately rising temperatures. • In 50+ years, the snow-covered period will shorten moderately with less persistent snow cover in Ontario and New York. Michigan is expected to maintain snow cover. • Under RCP 8.5, we expect similar trends to RCP 4.5 with more rapid transitions to rain over snow in the next 30-50 years. Ontario and Michigan will have less persistent snow cover. Michigan is expected to maintain snow cover. • In 50+ years, snowfall will transition to more rain and result in a lack of snow cover with significantly	• Under RCP 4.5, snowpack is expected to remain and limit the impacts of freeze/thaw processes on the AHTF in the next 30-50 years. • The transition to more rain after 50+ years will decrease snowpack and likely result in moderate increases in frost damage impacts during the winter months, primarily in Ontario and New York where snowpack will decline most. The shortened snow cover period will have limited impacts, as the early and late winter months will be less cold and increasing winter/spring precipitation, generally, should mitigate the decrease in spring moisture availability. • Under RCP 8.5, impacts at 30-50 years will be similar to RCP 4.5 at 50+ years. • In 50+ years, we expect the increases in temperature to mitigate the potential for frost damage rangewide due to an overall	• Under RCP 4.5, all populations continued to have a High rank for freeze/thaw buffering in 30-50 years. • In 50+ years, populations in Ontario and New York received a Medium rank for freeze/thaw buffer. Michigan maintained a High rank. • Under RCP 8.5, populations in Ontario and New York received a Medium rank for freeze/thaw buffer. Michigan maintained a High rank. • In 50+ years, all populations received a High rank for freeze/thaw buffer.

Factors	Change in Factor	Effect on the AHTF	Analysis (see Table 3-2)
	rising temperatures. The snow-covered period will decrease dramatically in New York and Ontario and moderately in Michigan during this period.	decrease in cold nights in Ontario and New York, and fewer cold nights coupled with remaining snowpack in Michigan.	
Climate Change: Drought (Section 4.5.2)	• Under RCP 4.5, we expect regional temperature increases of 6 °F (3.3 °C) and consistent to slightly increasing but more variable precipitation in the summer months in the snowbelt regions in 50+ years.	• Under RCP 4.5, drought conditions are anticipated to increase in the next 30-50 years, although the magnitude of the temperature increases should be in the 1.8 °F (1 °C) range and potential for increased precipitation and microsite buffering are anticipated to mitigate this effect within the range of variability experienced by the populations historically. • In 50+ years, temperature increases are anticipated to drive drought conditions coupled with more variable precipitation patterns, and the AHTF will likely experience drought conditions. We expect that these conditions will stress already very small populations.	• Under RCP 4.5, all populations maintained their current rank for Moisture within 30 to 50 years. • After 50+ years, all populations in the northern portion of the range dropped one rank for Moisture. All populations less than 10 individuals will become extirpated rangewide.

Factors	Change in Factor	Effect on the AHTF	Analysis (see Table 3-2)
	• Under RCP 8.5, we expect regional temperature increases 11.7 °F (6.5 °C) and consistent to slightly increasing but more variable precipitation in the summer months in the snowbelt regions in 50+ years.	• Under RCP 8.5, impacts will occur more quickly and we expect that at 30-50 years, drought conditions will affect the AHTF. • In 50+ years, temperature increases will continue to impact the AHTF, with increasing effect on very small populations.	• Under RCP 8.5, all populations in northern portion of the range dropped one rank for moisture in 30-50 years. All populations less than 10 individuals became extirpated rangewide. • After 50+ years, all populations in the northern portion of the range received a Low rank for Moisture. All populations with less than 20 individuals became extirpated rangewide.
Invasive Species (Sections 4.4 and 5.1.5)	• European swallowwort already occurs in or near all New York populations and at limited sites along the Niagara Escarpment in Ontario. European swallowwort is expected to spread into areas occupied by the AHTF in Ontario and remaining uninvaded populations in New York in 30-50 years and persist up to 50+ years. • Except under RCP 8.5, European swallowwort is expected to shift northward away from the New York populations in 50+ years (Figure 5-4). • European swallowort is not expected to spread to Michigan in the foreseable future.	• European swallowwort is highly competitive for soil resources and can densely occupy the AHTF habitat limiting its access to soil substrates and affect the AHTF with allelopathic compounds. In populations that are Managed, as we have defined it based on the current ownership of the property, we expect they will receive periodic to regular invasive species control, which will mitigate long-term increases in the invasive species. Unmanaged populations will become invaded.	• In Scenario 1, all populations in Ontario and New York that are Managed received a Medium rank for Substrate in 30-50 years in both scenarios and in 50+ years for RCP 4.5. All populations that are Managed in Ontario also received a Medium rank for Substrate after 50+ years under RCP 4.5. Unmanaged populations received a Low rank for Substrate in these scenarios and timeframes. • All populations in New York that have a currently depressed Substrate rank due to the presence of European swallowwort received a High rank for Substrate after 50+ years under RCP 8.5.

Factors	Change in Factor	Effect on the AHTF	Analysis (see Table 3-2)
	• Under RCP 8.5, the ALB is expected to become established in the eastern U.S. and Canada. We expect the most likely infestation in 30-50 years in the vicinity of the Ontario populations as the ALB occurs in regional proximity to these AHTF populations. After 50+ years, we expect that the ALB will spread from its current, more distant, locations in New York and Massachusetts to impact the New York populations as climate models predict this area of New York will be an area of rapid population growth potential by this time (Figure 5-5, Figure 5-7). • The ALB is not expected to spread to Michigan in the foreseeable future.	• The ALB is a canopy pest that can eliminate the deciduous canopy that the AHTF requires. Sugar maple is a preferred species of the ALB and the primary component of the forests where the AHTF occurs. The loss of these species due to an infestation of the ALB would cause a loss of the deciduous canopy and increase light levels dramatically leading to high evapotranspirative stress and lower thermal buffering at populations of the AHTF.	• In Scenario 2, all populations in Ontario received a Low rank for Light and Moisture condition in 30-50 years • After 50+ years, all New York populations also received a Low rank for Light and Moisture condition

5.2 Results

We found that our scenarios predict reductions in the number of AHTF populations and resiliency across the species range (Table 5-5); however, with a strong eventual shift to Medium and Low condition populations except for Scenario 1 at 30-50 years. Scenario 1 generally predicts declines of mostly High and Medium condition populations in Ontario and New York, with the number of Extirpated populations increasing from 22 to 34 after 50+ years. An unknown number of the predicted Low condition populations may also become extirpated. Scenario 2 generally predicts more rapid declines of High and Medium ranked populations in Ontario and New York, largely in Ontario, with the number of Extirpated populations increasing from 22 to 43 after 50+ years. An unknown number of the predicted Low condition populations in both scenarios may also become extirpated. The scenarios developed for this SSA and the predicted future condition for the 3Rs are summarized in Figure 5-8. As we did not incorporate impacts due to logging, quarrying, recreation, or other stressors that are expected to occur but not extensively across the species range, our results are likely conservative regarding potential changes in condition and future extirpations with regard to these factors.

5.2.1 The 3Rs

Scenario 1 predicts little change in resiliency after 30-50 years and a stronger decline after 50+ years. After 50+ years, a decrease of 30 to 9 High condition populations are predicted with extirpation expected for 10 of the smallest populations. Fifty-two populations, approximately half of the remaining populations, would be in a Low condition. The majority of the plants in the current populations would be in Medium condition populations after 50+ years. The declines associated with Scenario 1 are largely driven by the impacts of decreased snowpack and drought stress with eventual climatic shifts in 50+ years under RCP 4.5. Little change is expected due to European swallowwort in New York at either timeframe as most sites are currently managed; however, in Ontario the impacts of European swallowwort exacerbate the overall impact of climatic changes after 50+ years, as most sites are not managed. Figure 5-9 through Figure 5-11 depict the future condition under Scenario 1 after 50 years.

Scenario 2 predicts significant declines in resiliency earlier and more significant declines after 50+ years under RCP 8.5. After 30-50 years, impacts in Scenario 2 are expected to be similar to Scenario 1 at 50+ years; however, the invasion of the ALB in Ontario is predicted to cause a reduction of two additional High condition populations to Medium condition in only 30-50 years. Seven additional Medium condition populations are expected to become Low condition in only 30-50 years. The same 10 smallest populations are expected to be extirpated during this time, and a larger majority of populations are expected to be in a Low condition. Approximately 80 percent of the plants in the current populations would be in Medium condition populations. After 50+ years, an additional 10 of the smallest populations are expected to be extirpated due to additional climate stresses associated with drought. An additional High condition population is expected to become Medium condition; however, we expect an increase of 8 Medium condition populations due to a lower expected impact of freeze/thaw impacts on populations in New York and Ontario as winter temperatures rise to a point in which very cold days are less likely. The predicted decrease in impact of European swallowwort in New York has little change on the future condition in populations, as most sites are currently managed and the ALB is expected to invade all populations in this timeframe. While some impacts due to invasive species and freeze/thaw processes are reduced over time in Scenario 2, the strong impacts associated with drought conditions in RCP 8.5 and the invasion of the ALB in Ontario notably impact future condition. Figure 5-12 through Figure 5-14 depict the future condition under Scenario 1 after 50 years.

The representation of the AHTF remains fairly consistent under both scenarios over time (Figure 5-8). While the one population in Tennessee is predicted to be extirpated in both scenarios at any timeframe, due to its small population size, the population in Alabama is predicted to remain extant as the only population of the Appalachian Karst Unit. Neither of the scenarios eliminates the Alabama population, as the unique geomorphic position of the southern population is expected to buffer it somewhat from the effects of climate change and limit other potential stressors due to difficulty of access. All remaining populations addressed in this SSA will be in the Great Lakes Snowbelt Unit, and although there are declines in both sub-units, neither is predicted to be lost under any scenario or timeframe.

The redundancy of the AHTF predicted to decrease under both scenarios, but most under the higher emissions scenario and invasion by the ALB in Scenario 2. We expect that some portion of the Low condition populations may be lost in the future scenarios, in addition to the smallest populations predicted to be lost. In the Appalachian Karst Unit, redundancy is currently very low, and in any future scenario, redundancy is lost with only one population remaining. However, we are unaware of any catastrophic events likely to result in extirpation of the Alabama population. For the Great Lakes Snowbelt Unit, extirpated populations increase under all scenarios; however, these losses and reductions to Low condition do not appear to be concentrated in any particular area of the unit. Redundancy is expected to remain High in both scenarios after 50+ years. Losses of populations and reductions to Low condition are largely concentrated in the Niagara Escarpment sub-unit, specifically in Ontario, and increase under both scenarios, except the 30-50 year timeframe in Scenario 1. Overall redundancy is predicted to decline to Medium with 80 to 90 extant populations with 40 to 50 in Low condition remaining spread across the range from Michigan to Ontario. Contractions in the range in Ontario are predicted, as smaller populations on the peripheral areas of the main concentrations of population are lost. Losses in the Onondaga Escarpment sub-unit occur in both Scenarios; however, most of the remaining populations are in a Medium condition. Overall redundancy is predicted to remain fairly constant at Low as populations in this sub-unit are currently in close proximity to each other and there are far fewer populations in this sub-unit to begin with when compared to the Niagara Escarpment.

Table 5-5. Summary of future condition scenarios for the number of populations and plants (based on current condition counts) of the AHTF. Resiliency ranks are High, Medium, Low, and Extirpated. Unknown and Historical populations are not presented as the scenarios did not change these populations.

	Number of Populations			
	High	Medium	Low	Extirpated
Current Condition	30	57	30	22
Scenario 1 (30-50)	30	63	24	22
Scenario 1 (50+)	9	44	52	34
Scenario 2 (30-50)	7	37	61	34
Scenario 2 (50+)	6	46	44	43

	Number of Plants			
	High	Medium	Low	Extirpated
Current Condition	107375	13461	854	0
Scenario 1 (30-50)	105892	14933	865	0
Scenario 1 (50+)	48424	65499	7699	0
Scenario 2 (30-50)	15424	96977	9221	0
Scenario 2 (50+)	15307	100028	6168	0

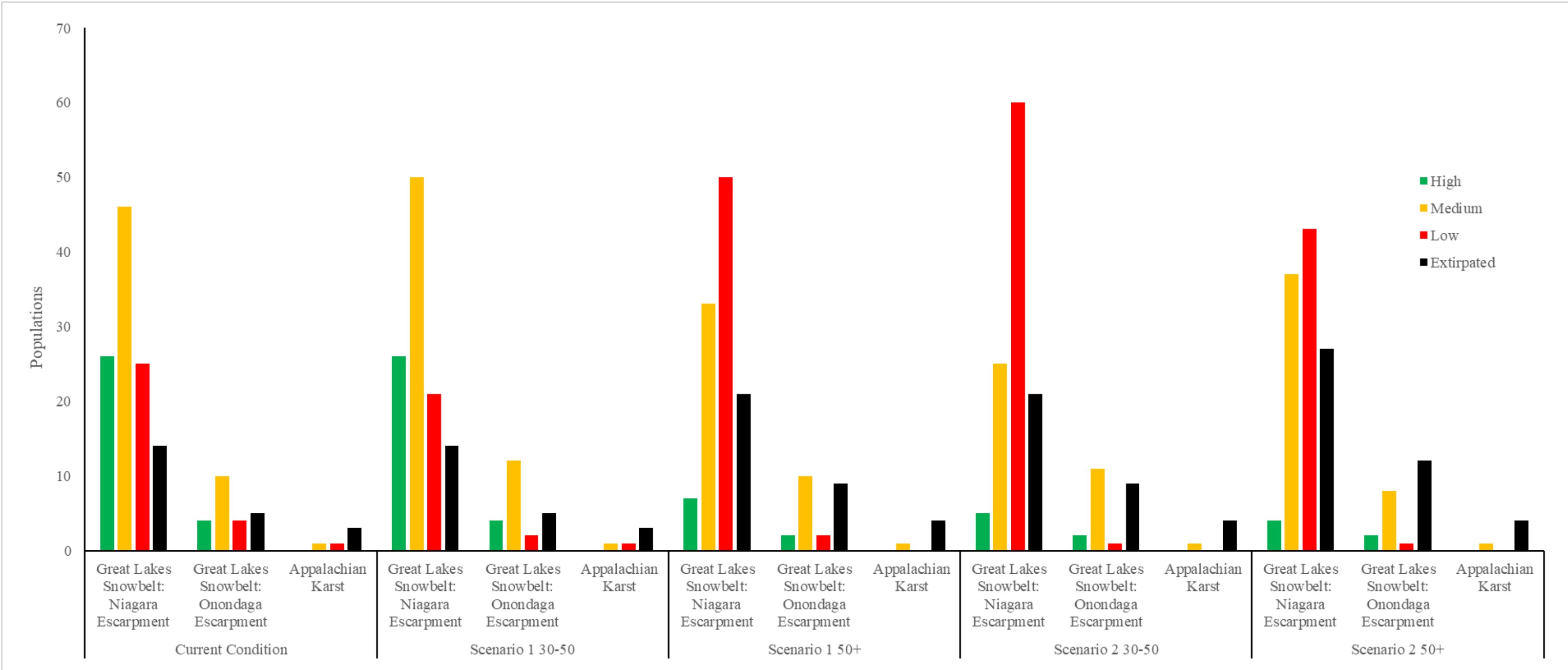


Figure 5-8. Summary of future condition of the AHTF by representative unit from two scenarios across two timeframes.

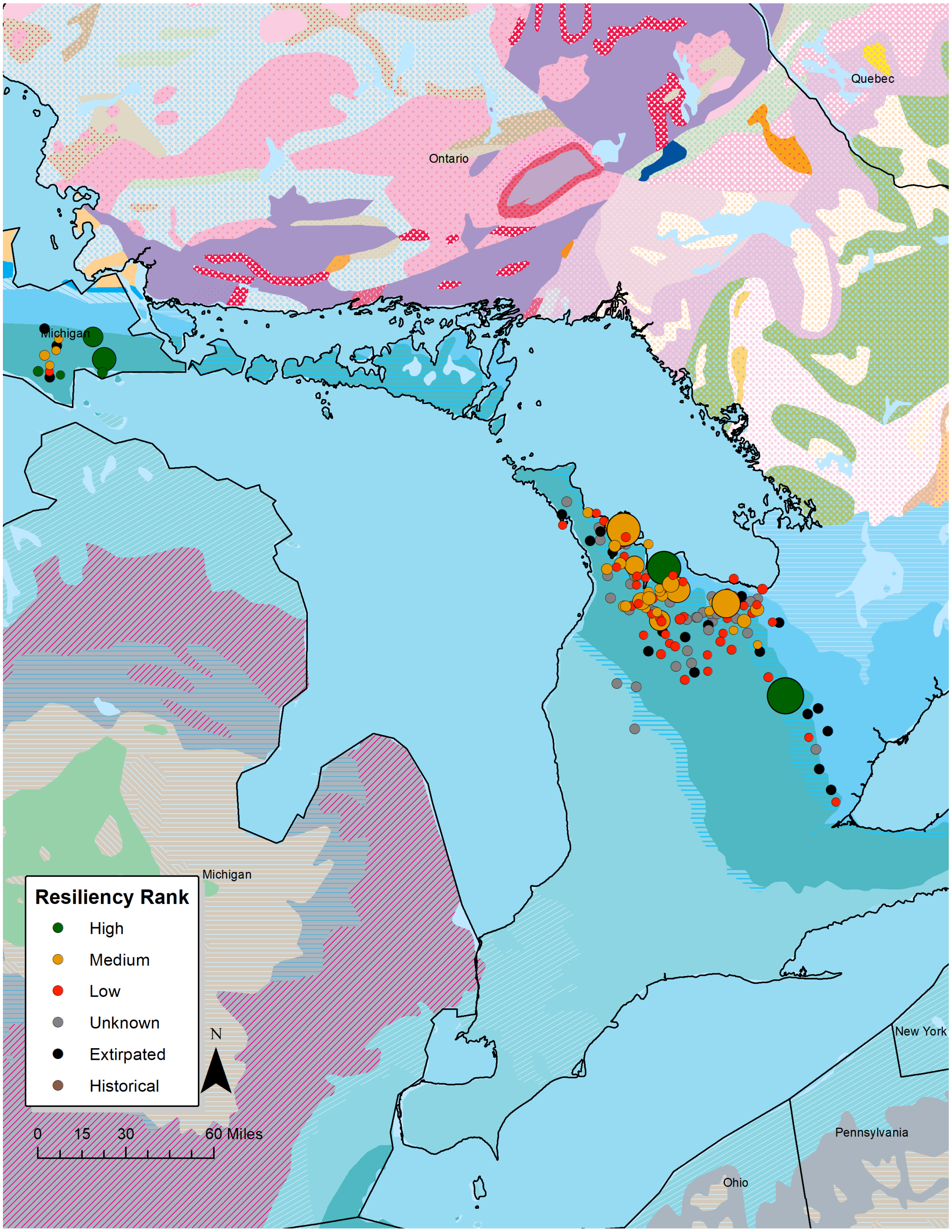


Figure 5-9. Map of the future condition in Scenario 1 at 50+ years for the Great Lakes Snowbelt: Niagara Escarpment Representative Sub-unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the teal green color underneath the majority of the populations represents the limestones associated with the Niagara Escarpment. The lighter blue green under the three Unknown populations represents the limestones associated with the Onondaga Escarpment. Locations have been randomized across 0.01 degrees of latitude and longitude.

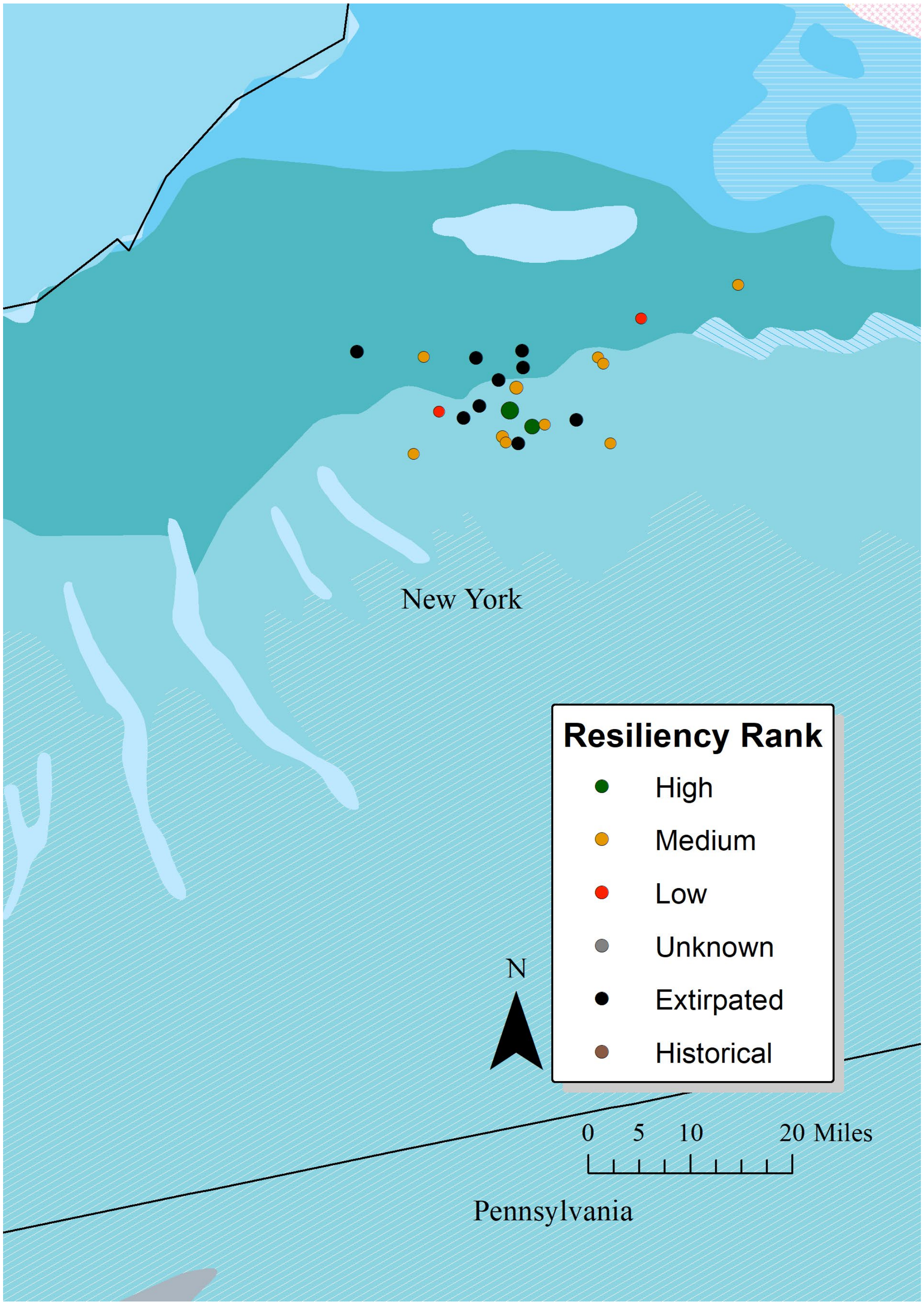


Figure 5-10. Map of the future condition in Scenario 1 at 50+ years for the Great Lakes Snowbelt: Onondaga Escarpment Representative Sub-unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the contact between the two blue green layers generally represents the dolostones associated with the Onondaga Escarpment. Locations have been randomized across 0.01 degrees of latitude and longitude resulting in some shifting north and south of this boundary in the image.

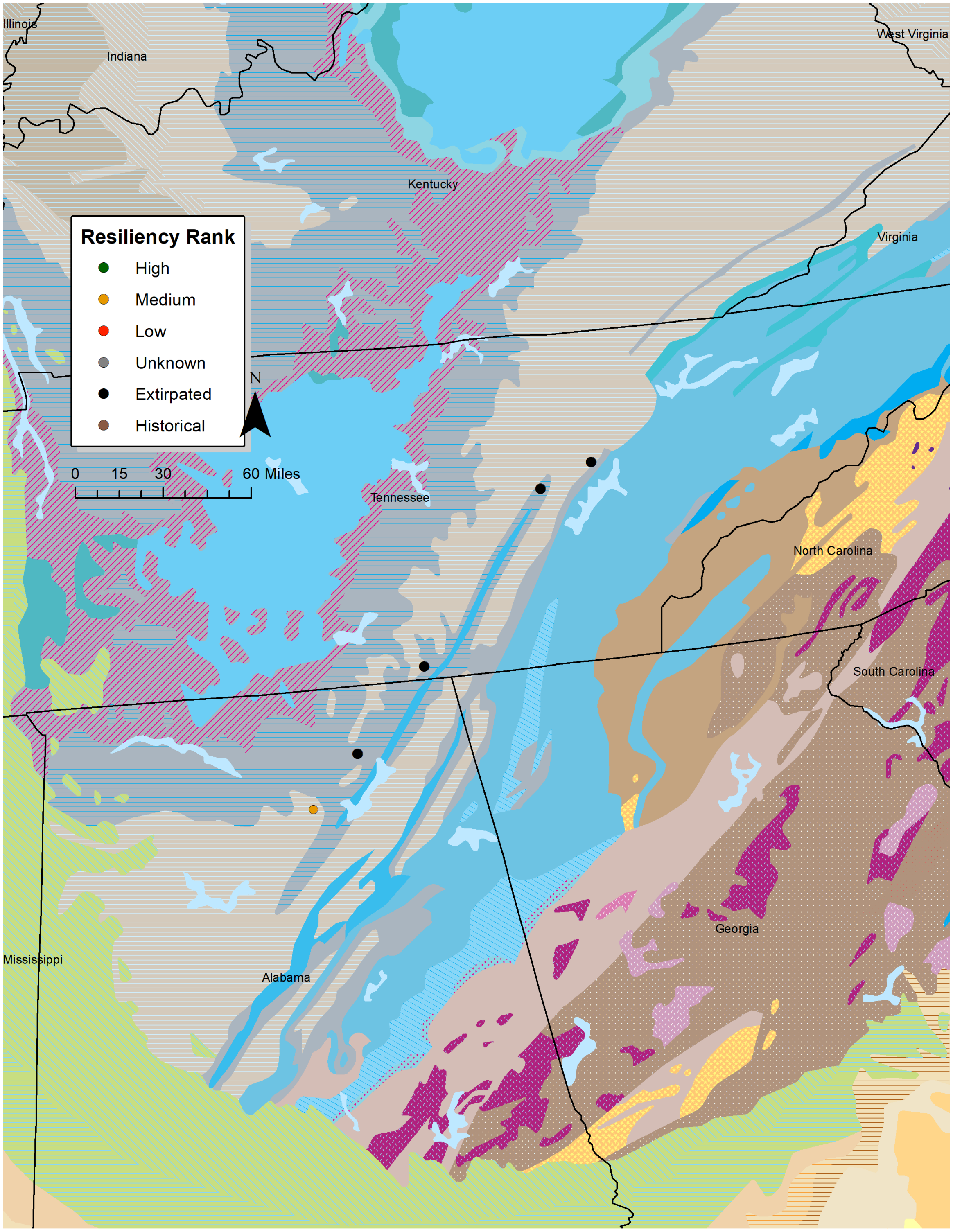


Figure 5-11. Map of the future condition in Scenario 1 at 50+ years for the Appalachian Karst Representative Unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the blue colors represent the limestones associated with the southern Appalachian Karst Unit. Locations have been randomized across 0.01 degrees of latitude and longitude resulting in some shifting away from these units in the image.

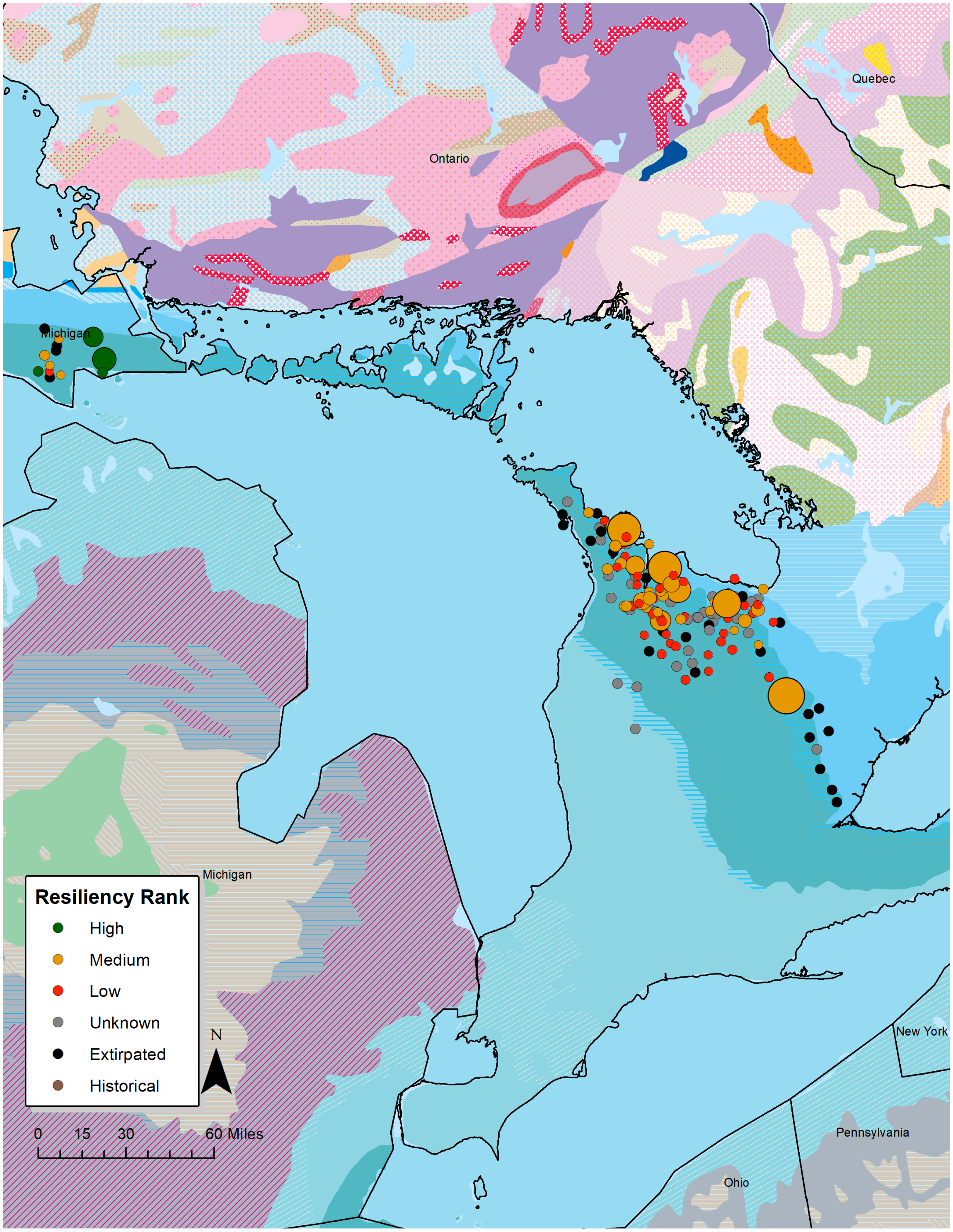


Figure 5-12. Map of the future condition in Scenario 2 at 50+ years for the Great Lakes Snowbelt: Niagara Escarpment Representative Sub-unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the teal green color underneath the majority of the populations represents the limestones associated with the Niagara Escarpment. The lighter blue green under the three Unknown populations represents the limestones associated with the Onondaga Escarpment. Locations have been randomized across 0.01 degrees of latitude and longitude.

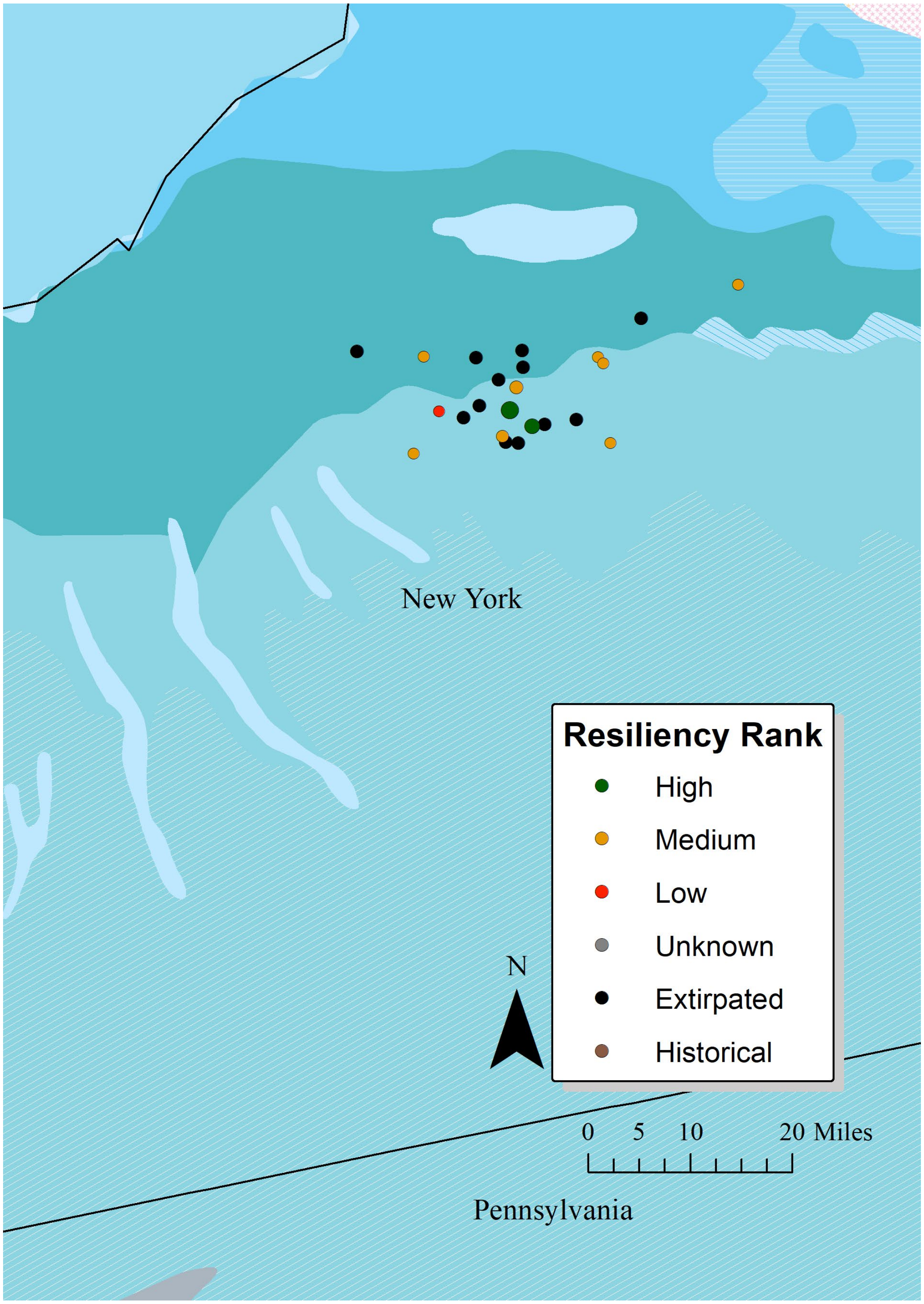


Figure 5-13. Map of the future condition in Scenario 2 at 50+ years for the Great Lakes Snowbelt: Onondaga Escarpment Representative Sub-unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the contact between the two blue green layers generally represents the dolostones associated with the Onondaga Escarpment. Locations have been randomized across 0.01 degrees of latitude and longitude resulting in some shifting north and south of this boundary in the image.

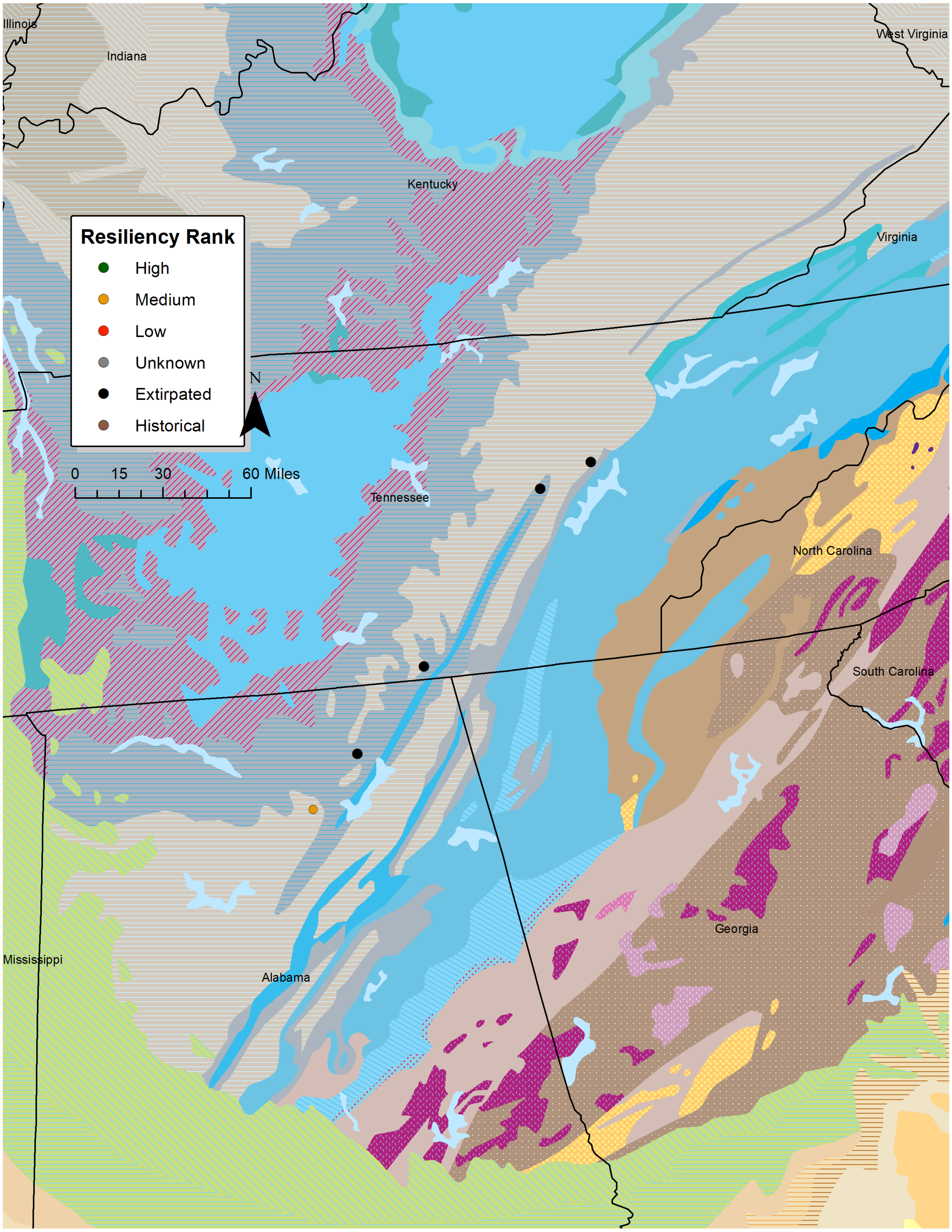


Figure 5-14. Map of the future condition in Scenario 1 at 50+ years for the Appalachian Karst Representative Unit by resiliency ranking and status. Populations are represented by circles that are scaled according to population size. Background layer represents underlying bedrock geology, and the blue colors represent the limestones associated with the southern Appalachian Karst Unit. Locations have been randomized across 0.01 degrees of latitude and longitude resulting in some shifting away from these units in the image.

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7 GLOSSARY

Antheridia: haploid reproductive structures containing the male gametes (i.e., sperm).

Archegonia: haploid reproductive structures containing the female gametes (i.e., egg).

Auriculate: having two lobes, often curved, often near the base of the frond.

Cordiform: having a heart-shape.

Element Occurrence: an area of land and/or water in which a species or natural community is, or was, present.

Escarpment: a long topographic break often with exposed clifflines separating two areas of different elevation.

Gametophyte: haploid life-stage that produces gametes and where sexual reproduction occurs. This life stage is often small only a single to few cell layers thick.

Heteromorphic: having different forms in different stages of a life cycle (i.e., small heart-shaped gametophyte, larger elongate sporophyte in the AHTF).

Historical Population: a population that has been noted in the literature or other source, but the location of which has not been confirmed or relocated since that time. Historical populations may or may not be extant and little to no other information is available regarding these populations.

Homosporous: producing spores of the same size and shape where the gametophyte gives rise to both antheridia and archegonia.

Leptosporangiate: having sporangia that were each formed from a single epidermal cell.

Limestone Pavement: exposed horizontal limestone bedrock with enlarged joints forming linear and extensive depressions in the surface.

Protonema: a filament of cells that forms following the germination of the spores of the AHTF.

Reniform: having a kidney shape.

Sinkhole: a geological feature formed from the dissolution of limestone that can vary from a shallow depression to a vertical cliff like opening into subterranean cave passages.

Sori: a cluster of spore producing structures on the underside of the sporophyte frond.

Sporeling: an intermediate life-stage observed in the AHTF consisting of a small, less distinctive, frond comparable to a seedling in other plants.

Sporophyte: diploid life-stage that produces spores and is the commonly observable life-stage of the AHTF.

Tetraploid: having four times the haploid number of chromosomes in a cell nucleus (i.e., 4n).

Unknown Population: a population with a known location confirmed to be extant but with no known abundance data. Unknown populations are considered extant but have an unknown number of individuals present.

Appendix A – Population Table

Country	State/Province	County	Population	Ownership	Protected	Managed	Last Visit	Last Survey	Conservative Abundance	Latitude	Longitude
United States	Michigan	Mackinac	Scherer (Hill Lake SW)	MNA	Yes	Yes	2016	2016	6900	46.1	-84.5
United States	Michigan	Mackinac	Hiawatha (Hill Lake E)	MNA	Yes	Yes	2016	2016	4846	46.1	-84.5
United States	Michigan	Mackinac	Pipeline	USFS - Hiawatha NF	Yes	Yes	2016	2016	46	46.1	-84.8
United States	Michigan	Mackinac	NW of East Lake (Carp River - North Branch)	USFS - Hiawatha NF	Yes	Yes	2016	2016	117	46.1	-84.8
United States	Michigan	Mackinac	SE of East Lake (East Lake Rd)	USFS - Hiawatha NF	Yes	Yes	2016	2016	537	46.1	-84.8
United States	Michigan	Mackinac	East Lake	USFS - Hiawatha NF	Yes	Yes	2016	2016	73	46.1	-84.8
United States	Michigan	Mackinac	SW of East Lake (Sugar Camp)	USFS - Hiawatha NF	Yes	Yes	2016	2016	170	46.1	-84.8
United States	Michigan	Mackinac	Taylor Creek	USFS - Hiawatha NF	Yes	Yes	2016	2016	567	46.1	-85
United States	Michigan	Mackinac	Gryke Site	USFS - Hiawatha NF	Yes	Yes	2014	2014	14	46.1	-84.8
United States	Michigan	Mackinac	Piehler Site	USFS - Hiawatha NF	Yes	Yes	2014	2014	3	46.1	-84.8
United States	Michigan	Mackinac	Cline Site	USFS - Hiawatha NF	Yes	Yes	2016	2016	5	46.1	-84.8
United States	Michigan	Mackinac	Hill Lake SE	Private	No	No	1999	Unknown	500	46.1	-84.5
United States	Michigan	Chippewa	Trout Lake	Private	No	No	2014	2014	0	46.2	-84.9
United States	New York	Onondaga	Lower Basin (colony 1)	NYS Parks - Clark Reservation	Yes	Yes	2012	2012	353	43	-76.1
United States	New York	Onondaga	Dead End Ravine (colony 2)	NYS Parks - Clark Reservation	Yes	Yes	2012	2012	436	43	-76.1
United States	New York	Onondaga	Grand Canyon (colony 3)	NYS Parks - Clark Reservation	Yes	Yes	2012	2012	1461	43	-76.1
United States	New York	Onondaga	Long Ravine (colony 4)	NYS Parks - Clark Reservation	Yes	Yes	2012	2012	93	43	-76.1
United States	New York	Onondaga	Sentinel Basin (colony 5)	NYS Parks - Clark Reservation	Yes	Yes	2012	2012	1033	43	-76.1
United States	New York	Onondaga	*Sentinel Basin 2 (colony 5 planted)	NYS Parks - Clark Reservation	Yes	Yes	2018	2018	5	43	-76.1
United States	New York	Onondaga	West Green Lake (Glacier Lake) (colony 6)	NYS Parks - Clark Reservation	Yes	Yes	2018	2018	31	43	-76.1
United States	New York	Onondaga	*Twin Basins (planted)	NYS Parks - Clark Reservation	Yes	Yes	2018	2018	11	43	-76.1
United States	New York	Onondaga	Rock Cut Gorge	Private - Fifth Garden LTD Partners	No	No	2012	2012	0	43	-76.1
United States	New York	Onondaga	Split Rock	NYSDEC - Split Rock UA	Yes	No	2011	2011	134	43	-76.2
United States	New York	Onondaga	*Split Rock 2 (planted)	NYSDEC - Split Rock UA	Yes	No	2018	2018	9	43	-76.2
United States	New York	Onondaga	Rams Gulch	NYSDOT	Yes	No	2019	2017	6	43	-76.1
United States	New York	Onondaga	Evergreen Lake 1 (colony 1) (Rock Face Gorge)	Private	No	No	2019	2017	16	43	-76
United States	New York	Onondaga	Evergreen Lake 2 (colony 2) (Sweet Road)	Private	No	No	2019	2017	8	43	-76
United States	New York	Onondaga	Green Pond	Private	No	No	Unknown	Unknown	0	43	-76
United States	New York	Onondaga	West White Lake	Private	No	No	Unknown	Unknown	0	43	-76
United States	New York	Onondaga	Whiskey Hollow	Private	No	No	Unknown	Unknown	0	43.1	-76.4
United States	New York	Onondaga	East White Lake	Private	No	No	Unknown	Unknown	0	43	-76
United States	New York	Madison	Horseshoe Gorge (CF colony 2)	NYS Parks - Chittenango Falls	Yes	Yes	2018	2018	182	43	-75.8
United States	New York	Madison	Powerline Ravine (Chips Trail) (CF colony 3)	NYS Parks - Chittenango Falls	Yes	Yes	2018	2018	72	43	-75.8
United States	New York	Madison	Stairway Talus (Falls / Gorge Trail) (CF colony1)	NYS Parks - Chittenango Falls	Yes	Yes	2012	2012	84	43	-75.8
United States	New York	Madison	Munnsville [should this be 1 and 2?]	Private	No	No	2011	2011	51	43	-75.6
United States	New York	Madison	Perryville Falls	Private	No	No	2018	2011	15	43	-75.8
United States	Tennessee	Marion	Kimball	Private	No	No	2016	2016	3	35	-85.7
United States	Tennessee	Roane	Post Oak Springs	Private	No	No	Unknown	Unknown	0	35.9	-84.6
United States	Tennessee	Cumberland	Grassy Cove	Private	No	No	Unknown	Unknown	0	35.8	-84.9

Country	State/Province	County	Population	Ownership	Protected	Managed	Last Visit	Last Survey	Conservative Abundance	Latitude	Longitude
United States	Alabama	Morgan	Newsome Sinks	Private	No	No	2016	2016	30	34.4	-86.6
United States	Alabama	Jackson	Fern Cave/Morgue Pit	USFWS - Wheeler NWR	Yes	Yes	2016	2016	0	34.7	-86.3
Canada	Ontario	Grey	Aberdeen	Private	No	No	2001	2001	330	44.2	-80.8
Canada	Ontario	Bruce	Adamsville 2.5 km NNW	Private	No	No	2004	2004	350	44.8	-81.1
Canada	Ontario	Grey	Annan 2.4 km SE	Private	No	No	1999	1999	300	44.6	-80.8
Canada	Ontario	Bruce	Barrow Bay South ANSI	Private	No	No	1993	1993	unknown	44.9	-81.1
Canada	Ontario	Bruce	Bass Lake Escarpment	CA	Yes	Yes	1993	1987	100	44.7	-80.9
Canada	Ontario	Grey	Bayview Escarpment	PP	Yes	Yes	2013	2013	15000	44.6	-80.7
Canada	Ontario	Grey	Beaver Valley - Upper	OMNRF	Yes	No	2013	2013	250	44.3	-80.5
Canada	Ontario	Grey	Beaver Valley - West Slope	Protected/Private	Partial	Unknown	1993	1993	unknown	44.3	-80.5
Canada	Ontario	Grey	Bognor NE	Protected/Private	Partial	Unknown	2012	1998	5000	44.5	-80.8
Canada	Ontario	Grey	Bognor SW	Protected/Private	Partial	Unknown	2010	2010	8000	44.5	-80.8
Canada	Ontario	Bruce	Boundary Bluffs Bruce Trail	Bruce Trail	Yes	Unknown	2009	Unknown	unknown	44.9	-81.1
Canada	Ontario	Bruce	Cape Croker - Malcom Bluff	First Nation	Unknown	Unknown	2011	2001	100	44.8	-81.1
Canada	Ontario	Bruce	Cape Croker - Sydney Bluff	First Nation	Unknown	Unknown	2013	2013	300	44.9	-81.1
Canada	Ontario	Bruce	Cape Dundas	Private	No	No	1996	1996	100	44.9	-81.1
Canada	Ontario	Grey	Castle Glen	Private	No	No	2006	2006	300	44.5	-80.3
Canada	Ontario	Grey	Castle Glen SE	Private	No	No	2012	2012	3	44.5	-80.3
Canada	Ontario	Grey	Chatsworth 3km South	NCC	Yes	Yes	2018	2018	8	44.4	-80.9
Canada	Ontario	Grey	Chatsworth L9 Con2	Private	No	No	2000	2000	30	44.4	-80.9
Canada	Ontario	Bruce	Clark's Corner	OMNRF	Yes	No	2013	2013	500	45	-81.3
Canada	Ontario	Bruce	Colpoys Bay	Private	No	No	1997	1997	unknown	44.8	-81.1
Canada	Ontario	Grey	Cruikshank 2 km NE	Private	No	No	1994	1994	unknown	44.6	-81
Canada	Ontario	Simcoe	Devil's Glen	Protected/Private	Partial	Partial	2013	2013	300	44.3	-80.2
Canada	Ontario	Grey	Duncan Escarpment PNR	Protected/Private	Partial	No	1993	1966	300	44.3	-80.4
Canada	Ontario	Grey	Duncan Lake South	Private	No	No	1985	1985	150	44.4	-80.3
Canada	Ontario	Grey	Duntroon W Escarpment	Private	No	No	2003	2003	30	44.4	-80.2
Canada	Ontario	Grey	Durham 3.6 km ENE	Private	No	No	2001	2001	20	44.1	-80.7
Canada	Ontario	Grey	Durham 5 km SE	Private	No	No	2002	2002	384	44.1	-80.7
Canada	Ontario	Grey	E of Desboro	Private	No	No	2012	2012	100	44.4	-80.9
Canada	Ontario	Grey	E of Desboro - Klondike	County Forest	No	No	2013	2013	46	44.4	-80.9
Canada	Ontario	Grey	East Wiarton Upland Woods	Protected/Private	Partial	Unknown	2001	2009	100	44.7	-81
Canada	Ontario	Grey	Feversham Gorge	CA	Yes	Yes	1999	1999	100	44.3	-80.3
Canada	Ontario	Grey	Gibraltar	Private	No	No	1983	1983	unknown	44.4	-80.3
Canada	Ontario	Bruce	Greenock 2 km SW	Private	No	No	1994	1994	unknown	44.1	-81.2
Canada	Ontario	Grey	Griersville SE	Private	No	No	2012	2012	unknown	44.5	-80.5
Canada	Ontario	Grey	Hepworth 1.5 km NE	Private	No	No	2001	2001	200	44.6	-81.1
Canada	Ontario	Bruce	Hope Bay 1.7 km SW	Private	No	No	2010	2010	100	44.9	-81.1
Canada	Ontario	Bruce	Hope Bay Cathedral Woods	Private	No	No	2001	2001	2020	44.9	-81.1
Canada	Ontario	Bruce	Hope Bay PNR/ANSI	Protected/Private	Partial	No	2008	1998	15000	44.9	-81.1
Canada	Ontario	Grey	Indian Creek Mgt Area 2.5 km SE Lindenwood	Private	No	No	1998	1998	700	44.6	-80.9
Canada	Ontario	Grey	Ingilis Falls	CA	Yes	Yes	2011	2003	100	44.5	-80.9

Country	State/Province	County	Population	Ownership	Protected	Managed	Last Visit	Last Survey	Conservative Abundance	Latitude	Longitude
Canada	Ontario	Grey	Irish Block	Private	No	No	2001	2001	20	44.5	-80.7
Canada	Ontario	Grey	Irish Block 2 km NW	Private	No	No	2012	2012	50	44.5	-80.7
Canada	Ontario	Bruce	Kemble Mountain	CA	Yes	Yes	2010	2010	4143	44.7	-80.9
Canada	Ontario	Grey	Kimberley Bruce Trail	Bruce Trail	Yes	Unknown	2002	2002	3	44.4	-80.5
Canada	Ontario	Grey	Kimberley Creek	Private	No	No	1993	1993	100	44.3	-80.5
Canada	Ontario	Grey	Kinghurst	Ontario Nature	Yes	Yes	2013	2013	100	44.3	-80.9
Canada	Ontario	Grey	Kolapore Escarpment	OMNRF	Yes	No	2010	2001	1600	44.3	-80.3
Canada	Ontario	Grey	Kolapore Swamp East	CA	Yes	Yes	2010	2010	unknown	44.4	-80.4
Canada	Ontario	Grey	Kolapore Upland Mgt Area (SE)	CA	Yes	Yes	2010	2010	111	44.3	-80.4
Canada	Ontario	Grey	Lady Bank 2 km WSW	Private	No	No	2008	2008	unknown	44.3	-80.4
Canada	Ontario	Bruce	Lake Charles 1 km S	Private	No	No	2012	2012	100	44.7	-81
Canada	Ontario	Bruce	Lake Charles 2 km E	Private	No	No	2011	2011	unknown	44.7	-81
Canada	Ontario	Grey	Lily Oak Forest	County Forest	No	No	2013	2013	600	44.4	-80.7
Canada	Ontario	Grey	Lindenwood SW	Bruce Trail & CA	Yes	Partial	2011	2011	50	44.6	-80.9
Canada	Ontario	Bruce	Lion's Head North	PP	Yes	Yes	2001	2001	7	44.9	-81.2
Canada	Ontario	Bruce	Lion's Head South	Bruce Trail	Yes	Unknown	2013	2013	16	44.9	-81.2
Canada	Ontario	Grey	Little Germany Management Area	CA	Yes	Yes	2010	2010	100	44.4	-80.5
Canada	Ontario	Grey	Massie Hills Management Area	Protected/Private	Partial	No	1984	1984	unknown	44.5	-80.8
Canada	Ontario	Grey	McIver Side Road	Private	No	No	2004	2004	200	44.8	-81.1
Canada	Ontario	Grey	McNab Lake	CA	Yes	Yes	2001	2001	807	44.6	-81
Canada	Ontario	Grey	Minniehill SSE	Private	No	No	2012	2012	50	44.5	-80.6
Canada	Ontario	Dufferin	Mono Cliffs PP	PP	Yes	Yes	2013	2013	18000	44	-80
Canada	Ontario	Grey	Mountain Lake Fen	Protected/Private	Partial	Unknown	2001	1998	3460	44.6	-81
Canada	Ontario	Halton	Mt. Nemo	CA	Yes	Yes	2013	2013	13	43.4	-79.8
Canada	Ontario	Grey	Mud Creek East	Private	No	No	2010	2010	unknown	44.6	-80.9
Canada	Ontario	Grey	Mud Creek North	CA	Yes	Yes	2002	2002	200	44.6	-80.9
Canada	Ontario	Grey	Mud Creek South/Shouldice ANSI	Protected/Private	Partial	No	2006	2006	500	44.6	-80.9
Canada	Ontario	Simcoe	Noisy River PP	PP	Yes	Yes	2013	2013	1500	44.3	-80.2
Canada	Ontario	Simcoe	Nottawasaga Lookout	Protected/Private	Partial	Unknown	2010	2010	41	44.4	-80.2
Canada	Ontario	Simcoe	Nottawasaga South	Private	No	No	2011	2011	unknown	44.4	-80.2
Canada	Ontario	Simcoe	Osler Bluff	Private	No	No	2012	2012	500	44.4	-80.2
Canada	Ontario	Bruce	Owen Sound 4.7 km NW	Private	No	No	1980	1980	unknown	44.5	-80.9
Canada	Ontario	Grey	Owen Sound Rifle Range	Private	No	No	1998	1998	500	44.6	-80.9
Canada	Ontario	Grey	Owen Sound South	Private	No	No	2010	2010	unknown	44.6	-80.9
Canada	Ontario	Grey	Owen Sound Southeast	Private	No	No	2003	2003	10	44.6	-80.9
Canada	Ontario	Bruce	Park Head	Private	No	No	2012	2012	750	44.6	-81.1
Canada	Ontario	Grey	Pottawatomi CA	CA	Yes	Yes	2013	2013	147	44.5	-80.9
Canada	Ontario	Grey	Pretty River PP	PP	Yes	Yes	2002	2002	25	44.4	-80.3
Canada	Ontario	Bruce	Purple Valley	Private	No	No	2013	2013	700	44.8	-81.1
Canada	Ontario	Grey	Rob Roy Management Area	CA	Yes	Yes	1993	1990	100	44.4	-80.3
Canada	Ontario	Grey	Rob Roy NE	Private	No	No	1993	1993	unknown	44.4	-80.3
Canada	Ontario	Grey	Robson Lakes	Protected/Private	Partial	Unknown	1993	1993	unknown	44.4	-80.7

Country	State/Province	County	Population	Ownership	Protected	Managed	Last Visit	Last Survey	Conservative Abundance	Latitude	Longitude
Canada	Ontario	Grey	Rockford 3.5 km SW	Private	No	No	1998	1998	25	44.5	-80.9
Canada	Ontario	Grey	Rocklyn Creek Valley East	CA	Yes	Yes	2001	2001	215	44.5	-80.6
Canada	Ontario	Grey	Rocklyn Creek Valley West	CA	Yes	Yes	1993	1993	unknown	44.5	-80.6
Canada	Ontario	Grey	Rocky Saugeen East	Private	No	No	2001	2001	116	44.2	-80.8
Canada	Ontario	Grey	Rocky Saugeen South	Private	No	No	2001	2001	282	44.2	-80.8
Canada	Ontario	Bruce	Rush Cove Corner	Private	No	No	2001	2001	1100	44.9	-81.1
Canada	Ontario	Halton	Scotsdale Farm	OHT	Yes	Yes	2010	2010	unknown	43.7	-80
Canada	Ontario	Bruce	SE Greenock	Private	No	No	1994	1994	unknown	44.1	-81.2
Canada	Ontario	Grey	Shallow Lake 2.8 km NNW	Private	No	No	2001	2001	62	44.6	-81
Canada	Ontario	Grey	Shouldice Forest/The Glen	Protected/Private	Partial	Unknown	2002	2002	1488	44.6	-81
Canada	Ontario	Grey	Skinner's Bluff	Protected/Private	Yes	Yes	2013	2013	1000	44.8	-81
Canada	Ontario	Grey	Slough of Despond	CA	Yes	Yes	2010	1992	200	44.7	-80.9
Canada	Ontario	Grey	Talisman Ski Area W of Kimberley	Private	No	No	2007	2007	30	44.4	-80.5
Canada	Ontario	Bruce	Teeswater SE on Teeswater River	Private	No	No	1994	1994	unknown	43.9	-81.2
Canada	Ontario	Grey	Telfer Creek	Bruce Trail	Yes	No	1999	1999	200	44.5	-80.8
Canada	Ontario	Grey	Vandeleur	Private	No	No	2011	2011	100	44.3	-80.5
Canada	Ontario	Dufferin	Violet Hill - Mono Cliffs North	Protected/Private	Partial	Unknown	2013	2013	300	44.1	-80.1
Canada	Ontario	Simcoe	Walker Quarry SW of Duntroon	Private	No	No	2013	2008	10500	44.4	-80.3
Canada	Ontario	Grey	Walter's Creek Headwaters Area NE	Private	No	No	1984	1984	unknown	44.4	-80.7
Canada	Ontario	Grey	Walter's Creek Headwaters Area SW	Private	No	No	1984	1984	unknown	44.4	-80.7
Canada	Ontario	Grey	Walter's Falls 3.5 km ESE	Private	No	No	2012	2012	unknown	44.5	-80.7
Canada	Ontario	Grey	West Rocks Management Area	CA	Yes	Yes	2004	1998	275	44.5	-80.9
Canada	Ontario	Peel	Wildwood Manor Ranch	Private	No	No	2001	2001	12	43.7	-79.9
Canada	Ontario	Grey	Williams Lake 1 km E	Private	No	No	1983	1983	unknown	44.4	-80.8
Canada	Ontario	Grey	Williamsford Bridge 2.2 km	Private	No	No	1990	1990	unknown	44.3	-80.8
Canada	Ontario	Grey	Woodford 2.3 km NNW	Private	No	No	2010	2010	3000	44.5	-80.7
Canada	Ontario	Grey	Woodford W Bruce Trail	Bruce Trail	Yes	No	2012	2008	100	44.6	-80.7
Canada	Ontario	Bruce	Lindsay Tract	Bruce County	No	No	2017	2017	12	45.05	-81.37
Canada	Ontario	Bruce	Miller Lake	Private	No	No	2018	2018	8	45.1	-81.4
Canada	Ontario	Bruce	W of Issac Lake	Private	No	No	2018	2018	30	44.8	-81.2
Canada	Ontario	Grey	Red Wing	Private	No	No	1932	1932	0	44.4	-80.4
Canada	Ontario	Bruce	Barrow Bay Village 3.2 km S	Private	No	No	1975	1975	0	44.9	-81.2
Canada	Ontario	Grey	Traverston Creek Village	County Forest	No	No	1981	1981	0	44.2	-80.6
Canada	Ontario	Grey	Mulock 7 miles S	Private	No	No	1966	1966	0	44.2	-80.9
Canada	Ontario	Peel	Inglewood Slope	Private	No	No	1958	1958	0	43.7	-79.9
Canada	Ontario	Peel	Credit Forks	PP	Yes	Yes	1976	1976	0	43.8	-79.9
Canada	Ontario	Grey	Near Scenic Caves E Banks	Private	No	No	1937	1937	0	44.3	-80.7
Canada	Ontario	Simcoe	Stayner	Private	No	No	1970	1970	0	44.4	-80
Canada	Ontario	Halton	Milton Heights	Private	No	No	1977	1977	0	43.5	-79.9
Canada	Ontario	Halton	Halton Forest North	County Forest	No	No	1981	1981	0	43.5	-80
Canada	Ontario	Grey	McKinney's Hill/Nottawasaga Bluffs CA	Protected/Private	Partial	Partial	1983	1983	0	44.2	-80.2
Canada	Ontario	Peel	Caledon Mountain Slope Forest	Private	No	No	1993	1993	0	43.8	-79.9

Country	State/Province	County	Population	Ownership	Protected	Managed	Last Visit	Last Survey	Conservative Abundance	Latitude	Longitude
Canada	Ontario	Bruce	Between Boat and Spry Lake Bluewater Outdoor Center	Private	No	No	1996	1996	0	44.7	-81.2
Canada	Ontario	Grey	Jones's Falls	CA	Yes	Yes	1901	Unknown	unknown	44.5	-81
Canada	Ontario	Grey	Wiarton area	Unknown	Unknown	Unknown	1919	Unknown	unknown	44.7	-81.2
Canada	Ontario	Grey	Saugeen River	Unknown	Unknown	Unknown	1960	Unknown	unknown	44.1	-80.8
Canada	Ontario	Bruce	1-1.5 Miles E Stokes Bay	Unknown	Unknown	Unknown	1952	Unknown	unknown	45	-81.3
Canada	Ontario	Grey	Hayward Falls, Rocky Saugeen River	Unknown	Unknown	Unknown	1962	Unknown	unknown	44.2	-80.7
Canada	Ontario	Grey	5 KM S Singhampton	Unknown	Unknown	Unknown	1971	Unknown	unknown	44.3	-80.3
Canada	Ontario	Simcoe	East of Edward Lake	Unknown	Unknown	Unknown	1976	Unknown	unknown	44.4	-80.2
Canada	Ontario	Grey	1 Mile E Eugenia	Unknown	Unknown	Unknown	1976	Unknown	unknown	44.3	-80.5
Canada	Ontario	Grey	3 Mile E Eugenia	Unknown	Unknown	Unknown	1976	Unknown	unknown	44.3	-80.5
Canada	Ontario	Grey	6 - 7 KM NE Hepworth	Private	Unknown	Unknown	1980	Unknown	unknown	44.65	-81.1
Canada	Ontario	Grey	3.5 KM W Goring	Unknown	Unknown	Unknown	1984	Unknown	unknown	44.4	-80.7

Appendix B – Summary of Current Condition of AHTF

Colors indicate representative units as described in Section 3.3.2

Country	State/Province	County	Population	EO Rank	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Michigan	Mackinac	Scherer (Hill Lake SW)	A	High		High	High	High	Medium	High	High	Low
United States	Michigan	Mackinac	Hiawatha (Hill Lake E)	A	High		High	High	High	Medium	High	High	Low
United States	Michigan	Mackinac	Pipeline	CD	Low	Low	Medium	Medium	Medium	Medium	High	Low	Low
United States	Michigan	Mackinac	NW of East Lake (Carp River - North Branch)	B	Medium	Medium	High	High	High	High	High	High	Low
United States	Michigan	Mackinac	SE of East Lake (East Lake Rd)	B	High	Medium	High	Medium	Medium	Medium	High	High	Low
United States	Michigan	Mackinac	East Lake	C	Low	Low	High	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	SW of East Lake (Sugar Camp)	B	Medium	Low	High	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	Taylor Creek	AB	High	Medium	High	High	High	High	High	High	Low
United States	Michigan	Mackinac	Gryke Site	Unknown	Low	Low	High	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	Pichler Site	Unknown	Low	Medium	Medium	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	Cline Site	Unknown	Low		High	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	Hill Lake SE	A	High		High	High	High	High	High	High	High
United States	Michigan	Chippewa	Trout Lake	F	Extirpated	Extirpated	Extirpated	High	High	High	High	Extirpated	Low
United States	New York	Onondaga	Lower Basin (colony 1)	BC	Medium	High	High	High	Medium	Medium	High	High	Low
United States	New York	Onondaga	Dead End Ravine (colony 2)	BC	High	Medium	High	High	Medium	Medium	High	High	Low
United States	New York	Onondaga	Grand Canyon (colony 3)	AB	High	High	High	High	Medium	Medium	High	High	Low
United States	New York	Onondaga	Long Ravine (colony 4)	BC	Low	Low	Medium	High	Medium	Medium	High	Low	Low
United States	New York	Onondaga	Sentinel Basin (colony 5)	BC	High	High	High	High	Medium	Medium	High	High	Low
United States	New York	Onondaga	*Sentinel Basin 2 (colony 5 planted)	I	Low		Low	Medium	Medium	Medium	High	Low	Low
United States	New York	Onondaga	West Green Lake (Glacier Lake) (colony 6)	CD	Low	Medium	Medium	Medium	Medium	Medium	High	Medium	Low
United States	New York	Onondaga	*Twin Basins (planted)	I	Low		Medium	High	Medium	Medium	High	Medium	Low
United States	New York	Onondaga	Rock Cut Gorge	X	Extirpated	Extirpated	Extirpated	Medium	Low	Low	High	Extirpated	Low
United States	New York	Onondaga	Split Rock	B	Medium	Medium	High	High	Low	Low	High	Medium	Low
United States	New York	Onondaga	*Split Rock 2 (planted)	I	Low		Low	High	Medium	Medium	High	Medium	Low
United States	New York	Onondaga	Rams Gulch	C	Low	Medium	Low	Medium	Low	Low	High	Low	Low
United States	New York	Onondaga	Evergreen Lake 1 (colony 1) (Rock Face Gorge)	CD	Low	Medium	Medium	High	High	Medium	High	Medium	Low
United States	New York	Onondaga	Evergreen Lake 2 (colony 2) (Sweet Road)	C	Low	Low	Low	Medium	Low	Low	High	Low	Low
United States	New York	Onondaga	Green Pond	X	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	New York	Onondaga	West White Lake	X	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	New York	Onondaga	Whiskey Hollow	X	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	New York	Onondaga	East White Lake	X	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	New York	Madison	Horseshoe Gorge (CF colony 2)	C	Medium	Medium	High	High	Medium	Medium	High	Medium	Low
United States	New York	Madison	Powerline Ravine (Chips Trail) (CF colony 3)	CD	Low	Medium	High	High	Medium	Medium	High	Medium	Low
United States	New York	Madison	Stairway Talus (Falls / Gorge Trail) (CF colony1)	CD	Low	High	High	High	Medium	Medium	High	Medium	Low
United States	New York	Madison	Munnsville [should this be 1 and 2?]	C	Low	Medium		High	High	High	High	Medium	Low
United States	New York	Madison	Perryville Falls	CD	Low	Low		High	Medium	High	High	Medium	Low
United States	Tennessee	Marion	Kimball	D	Low	Low	Low	High	High	Low	Medium	Low	Low
United States	Tennessee	Roane	Post Oak Springs	X	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	Tennessee	Cumberland	Grassy Cove	X	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High

Country	State/Province	County	Population	EO Rank	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Alabama	Morgan	Newsome Sinks	Unknown	Low	Medium	High	High	High	High	High	Medium	Low
United States	Alabama	Jackson	Fern Cave/Morgue Pit	X	Extirpated	Extirpated	Extirpated	High	High	High	High	Extirpated	High
Canada	Ontario	Grey	Aberdeen	AB	Medium						High	Medium	High
Canada	Ontario	Bruce	Adamsville 2.5 km NNW	Unknown	Medium						High	Medium	High
Canada	Ontario	Grey	Annan 2.4 km SE	B	Medium						High	Medium	High
Canada	Ontario	Bruce	Barrow Bay South ANSI	B							High	Unknown	High
Canada	Ontario	Bruce	Bass Lake Escarpment	B	Medium						High	Medium	High
Canada	Ontario	Grey	Bayview Escarpment	A	High	High					High	High	Medium
Canada	Ontario	Grey	Beaver Valley - Upper	AB	Medium						High	Medium	Medium
Canada	Ontario	Grey	Beaver Valley - West Slope	C							High	Unknown	High
Canada	Ontario	Grey	Bognor NE	A	High						High	High	High
Canada	Ontario	Grey	Bognor SW	A	High						High	High	Medium
Canada	Ontario	Bruce	Boundary Bluffs Bruce Trail	Unknown							High	Unknown	High
Canada	Ontario	Bruce	Cape Croker - Malcom Bluff	C	Medium	Low					High	Medium	High
Canada	Ontario	Bruce	Cape Croker - Sydney Bluff	B	Medium						High	Medium	Medium
Canada	Ontario	Bruce	Cape Dundas	H	Medium						High	Medium	High
Canada	Ontario	Grey	Castle Glen	Unknown	Medium						High	Medium	High
Canada	Ontario	Grey	Castle Glen SE	Unknown	Low						High	Low	High
Canada	Ontario	Grey	Chatsworth 3km South	Unknown	Low	Medium					High	Medium	Medium
Canada	Ontario	Grey	Chatsworth L9 Con2	E	Low						High	Low	High
Canada	Ontario	Bruce	Clark's Corner	B	High	High			Medium		High	High	Low
Canada	Ontario	Bruce	Colpoys Bay	CD							High	Unknown	High
Canada	Ontario	Grey	Cruikshank 2 km NE	E							High	Unknown	High
Canada	Ontario	Simcoe	Devil's Glen	BC	Medium	Low			Medium	Low	High	Medium	Low
Canada	Ontario	Grey	Duncan Escarpment PNR	AB	Medium						High	Medium	High
Canada	Ontario	Grey	Duncan Lake South	Unknown	Medium	Low					High	Medium	High
Canada	Ontario	Grey	Duntroon W Escarpment	C	Low						High	Low	High
Canada	Ontario	Grey	Durham 3.6 km ENE	C	Low						High	Low	High
Canada	Ontario	Grey	Durham 5 km SE	Unknown	Medium						High	Medium	High
Canada	Ontario	Grey	E of Desboro	Unknown	Medium						High	Medium	Medium
Canada	Ontario	Grey	E of Desboro - Klondike	C	Low	Low					High	Low	Medium
Canada	Ontario	Grey	East Wiarton Upland Woods	C	Medium						High	Medium	High
Canada	Ontario	Grey	Feversham Gorge	BC	Medium						High	Medium	High
Canada	Ontario	Grey	Gibraltar	BC							High	Unknown	High
Canada	Ontario	Bruce	Greenock 2 km SW	E							High	Unknown	High
Canada	Ontario	Grey	Griersville SE	Unknown							High	Unknown	Medium
Canada	Ontario	Grey	Hepworth 1.5 km NE	Unknown	Medium						High	Medium	High
Canada	Ontario	Bruce	Hope Bay 1.7 km SW	A	Medium						High	Medium	Medium
Canada	Ontario	Bruce	Hope Bay Cathedral Woods	A	High						High	High	High
Canada	Ontario	Bruce	Hope Bay PNR/ANSI	A	High						High	High	High
Canada	Ontario	Grey	Indian Creek Mgt Area 2.5 km SE Lindenwood	A	High						High	High	High
Canada	Ontario	Grey	Ingilis Falls	A	Medium		Medium		Medium		High	Medium	Medium

Country	State/Province	County	Population	EO Rank	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Irish Block	E	Low						High	Low	High
Canada	Ontario	Grey	Irish Block 2 km NW	Unknown	Low						High	Low	Medium
Canada	Ontario	Bruce	Kemble Mountain	A	High	Low					High	Medium	Medium
Canada	Ontario	Grey	Kimberley Bruce Trail	Unknown	Low						High	Low	High
Canada	Ontario	Grey	Kimberley Creek	AB	Medium						High	Medium	High
Canada	Ontario	Grey	Kinghurst	C	Medium	Low				Low	High	Low	Low
Canada	Ontario	Grey	Kolapore Escarpment	A	High						High	High	High
Canada	Ontario	Grey	Kolapore Swamp East	Unknown							High	Unknown	Medium
Canada	Ontario	Grey	Kolapore Upland Mgt Area (SE)	B	Medium	Low					High	Medium	Medium
Canada	Ontario	Grey	Lady Bank 2 km WSW	Unknown							High	Unknown	High
Canada	Ontario	Bruce	Lake Charles 1 km S	Unknown	Medium						High	Medium	High
Canada	Ontario	Bruce	Lake Charles 2 km E	Unknown							High	Unknown	Medium
Canada	Ontario	Grey	Lily Oak Forest	B	High	Low				Low	High	Medium	Low
Canada	Ontario	Grey	Lindenwood SW	Unknown	Low						High	Low	Medium
Canada	Ontario	Bruce	Lion's Head North	D	Low				Medium		High	Low	High
Canada	Ontario	Bruce	Lion's Head South	D	Low				Medium		High	Low	Medium
Canada	Ontario	Grey	Little Germany Management Area	Unknown	Medium						High	Medium	Medium
Canada	Ontario	Grey	Massie Hills Management Area	H							High	Unknown	High
Canada	Ontario	Grey	McIver Side Road	BC	Medium						High	Medium	High
Canada	Ontario	Grey	McNab Lake	B	High						High	High	High
Canada	Ontario	Grey	Minniehill SSE	Unknown	Low						High	Low	Medium
Canada	Ontario	Dufferin	Mono Cliffs PP	BC	High	High			Medium		High	High	Low
Canada	Ontario	Grey	Mountain Lake Fen	A	High						High	High	High
Canada	Ontario	Halton	Mt. Nemo	D	Low	Medium	Low		Low		High	Low	Low
Canada	Ontario	Grey	Mud Creek East	BC			Medium				High	Unknown	Medium
Canada	Ontario	Grey	Mud Creek North	BC	Medium						High	Medium	High
Canada	Ontario	Grey	Mud Creek South/Shouldice ANSI	BC	High	Low				Low	High	Medium	High
Canada	Ontario	Simcoe	Noisy River PP	A	High						High	High	Medium
Canada	Ontario	Simcoe	Nottawasaga Lookout	D	Low						High	Low	Medium
Canada	Ontario	Simcoe	Nottawasaga South	D							High	Unknown	Medium
Canada	Ontario	Simcoe	Osler Bluff	Unknown	High	Low				Low	High	Medium	Low
Canada	Ontario	Bruce	Owen Sound 4.7 km NW	BC							High	Unknown	High
Canada	Ontario	Grey	Owen Sound Rifle Range	C	High						High	High	High
Canada	Ontario	Grey	Owen Sound South	Unknown							High	Unknown	Medium
Canada	Ontario	Grey	Owen Sound Southeast	Unknown	Low						High	Low	High
Canada	Ontario	Bruce	Park Head	Unknown	High						High	High	Medium
Canada	Ontario	Grey	Pottawatomi CA	B	Medium		Low				High	Medium	Medium
Canada	Ontario	Grey	Pretty River PP	C	Low						High	Low	High
Canada	Ontario	Bruce	Purple Valley	A	High	High				Low	High	High	Low
Canada	Ontario	Grey	Rob Roy Management Area	BC	Medium						High	Medium	High
Canada	Ontario	Grey	Rob Roy NE	Unknown							High	Unknown	High
Canada	Ontario	Grey	Robson Lakes	B							High	Unknown	High

Country	State/Province	County	Population	EO Rank	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Rockford 3.5 km SW	C	Low						High	Low	High
Canada	Ontario	Grey	Rocklyn Creek Valley East	BC	Medium						High	Medium	High
Canada	Ontario	Grey	Rocklyn Creek Valley West	BC							High	Unknown	High
Canada	Ontario	Grey	Rocky Saugeen East	B	Medium						High	Medium	High
Canada	Ontario	Grey	Rocky Saugeen South	B	Medium						High	Medium	High
Canada	Ontario	Bruce	Rush Cove Corner	A	High						High	High	High
Canada	Ontario	Halton	Scotsdale Farm	Unknown							High	Unknown	Medium
Canada	Ontario	Bruce	SE Greenock	E							High	Unknown	High
Canada	Ontario	Grey	Shallow Lake 2.8 km NNW	C	Low	Low				Low	High	Low	High
Canada	Ontario	Grey	Shouldice Forest/The Glen	AB	High					Low	High	High	High
Canada	Ontario	Grey	Skinner's Bluff	A	High						High	High	Medium
Canada	Ontario	Grey	Slough of Despond	H	Medium						High	Medium	High
Canada	Ontario	Grey	Talisman Ski Area W of Kimberley	Unknown	Low						High	Low	High
Canada	Ontario	Bruce	Teeswater SE on Teeswater River	E							High	Unknown	High
Canada	Ontario	Grey	Telfer Creek	B	Medium						High	Medium	High
Canada	Ontario	Grey	Vandeleur	Unknown	Medium						High	Medium	Medium
Canada	Ontario	Dufferin	Violet Hill - Mono Cliffs North	Unknown	Medium						High	Medium	Medium
Canada	Ontario	Simcoe	Walker Quarry SW of Duntroon	Unknown	High						High	High	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area NE	H							High	Unknown	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area SW	H							High	Unknown	High
Canada	Ontario	Grey	Walter's Falls 3.5 km ESE	H							High	Unknown	Medium
Canada	Ontario	Grey	West Rocks Management Area	B	Medium						High	Medium	High
Canada	Ontario	Peel	Wildwood Manor Ranch	E	Low						High	Low	High
Canada	Ontario	Grey	Williams Lake 1 km E	H							High	Unknown	High
Canada	Ontario	Grey	Williamsford Bridge 2.2 km	BC							High	Unknown	High
Canada	Ontario	Grey	Woodford 2.3 km NNW	B	High						High	High	Medium
Canada	Ontario	Grey	Woodford W Bruce Trail	Unknown	Medium						High	Medium	High
Canada	Ontario	Bruce	Lindsay Tract	Unknown	Low						High	Low	Medium
Canada	Ontario	Bruce	Miller Lake	Unknown	Low						High	Low	Medium
Canada	Ontario	Bruce	W of Issac Lake	Unknown	Low						High	Low	Medium
Canada	Ontario	Grey	Red Wing	X	Extirpated						High	Extirpated	High
Canada	Ontario	Bruce	Barrow Bay Village 3.2 km S	X	Extirpated					Low	High	Extirpated	High
Canada	Ontario	Grey	Traverston Creek Village	X	Extirpated						High	Extirpated	High
Canada	Ontario	Grey	Mulock 7 miles S	X	Extirpated					Low	High	Extirpated	High
Canada	Ontario	Peel	Inglewood Slope	X	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Peel	Credit Forks	X	Extirpated						High	Extirpated	High
Canada	Ontario	Grey	Near Scenic Caves E Banks	X	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Simcoe	Stayner	X	Extirpated						High	Extirpated	High
Canada	Ontario	Halton	Milton Heights	X	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Halton	Halton Forest North	X	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Grey	McKinney's Hill/Nottawasaga Bluffs CA	X	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Peel	Caledon Mountain Slope Forest	X	Extirpated				Low	Low	High	Extirpated	High

Country	State/Province	County	Population	EO Rank	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Bruce	Between Boat and Spry Lake Bluewater Outdoor Center	X	Extirpated						High	Extirpated	High
Canada	Ontario	Grey	Jones's Falls	H							High	Historical	High
Canada	Ontario	Grey	Wiarton area	H							High	Historical	High
Canada	Ontario	Grey	Saugeen River	H							High	Historical	High
Canada	Ontario	Bruce	1-1.5 Miles E Stokes Bay	H							High	Historical	High
Canada	Ontario	Grey	Hayward Falls, Rocky Saugeen River	H							High	Historical	High
Canada	Ontario	Grey	5 KM S Singhampton	H							High	Historical	High
Canada	Ontario	Simcoe	East of Edward Lake	H							High	Historical	High
Canada	Ontario	Grey	1 Mile E Eugenia	H							High	Historical	High
Canada	Ontario	Grey	3 Mile E Eugenia	H							High	Historical	High
Canada	Ontario	Grey	6 - 7 KM NE Hepworth	H							High	Historical	High
Canada	Ontario	Grey	3.5 KM W Goring	H							High	Historical	High

Appendix C – Summary of Future Condition Scenarios

Scenerio 1 (30-50 years)

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Michigan	Mackinac	Scherer (Hill Lake SW)	High		High	High	High	Medium	High	High	Low
United States	Michigan	Mackinac	Hiawatha (Hill Lake E)	High		High	High	High	Medium	High	High	Low
United States	Michigan	Mackinac	Pipeline	Low	Low	Medium	Medium	Medium	Medium	High	Medium	Low
United States	Michigan	Mackinac	NW of East Lake (Carp River - North Branch)	Medium	Medium	High	High	High	High	High	High	Low
United States	Michigan	Mackinac	SE of East Lake (East Lake Rd)	High	Medium	High	Medium	Medium	Medium	High	High	Low
United States	Michigan	Mackinac	East Lake	Low	Low	High	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	SW of East Lake (Sugar Camp)	Medium	Low	High	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	Taylor Creek	High	Medium	High	High	High	High	High	High	Low
United States	Michigan	Mackinac	Gryke Site	Low	Low	High	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	Piehler Site	Low	Medium	Medium	High	High	High	High	Medium	Low
United States	Michigan	Mackinac	Cline Site	Low		High	High	High	High	High	High	Low
United States	Michigan	Mackinac	Hill Lake SE	High		High	High	High	High	High	High	High
United States	Michigan	Chippewa	Trout Lake	Extirpated	Extirpated	Extirpated	High	High	High	High	Extirpated	Low
United States	New York	Onondaga	Lower Basin (colony 1)	Medium	High	High	High	Medium	Medium	High	High	Low
United States	New York	Onondaga	Dead End Ravine (colony 2)	High	Medium	High	High	Medium	Medium	High	High	Low
United States	New York	Onondaga	Grand Canyon (colony 3)	High	High	High	High	Medium	Medium	High	High	Low
United States	New York	Onondaga	Long Ravine (colony 4)	Low	Low	Medium	High	Medium	Medium	High	Medium	Low
United States	New York	Onondaga	Sentinel Basin (colony 5)	High	High	High	High	Medium	Medium	High	High	Low
United States	New York	Onondaga	*Sentinel Basin 2 (colony 5 planted)	Low		Low	Medium	Medium	Medium	High	Medium	Low
United States	New York	Onondaga	West Green Lake (Glacier Lake) (colony 6)	Low	Medium	Medium	Medium	Medium	Medium	High	Medium	Low
United States	New York	Onondaga	*Twin Basins (planted)	Low		Medium	High	Medium	Medium	High	Medium	Low
United States	New York	Onondaga	Rock Cut Gorge	Extirpated	Extirpated	Extirpated	Medium	Low	Low	High	Extirpated	Low
United States	New York	Onondaga	Split Rock	Medium	Medium	High	High	Low	Low	High	Medium	Low
United States	New York	Onondaga	*Split Rock 2 (planted)	Low		Low	High	Low	Medium	High	Medium	Low
United States	New York	Onondaga	Rams Gulch	Low	Medium	Low	Medium	Low	Low	High	Low	Low
United States	New York	Onondaga	Evergreen Lake 1 (colony 1) (Rock Face Gorge)	Low	Medium	Medium	High	Low	Medium	High	Medium	Low
United States	New York	Onondaga	Evergreen Lake 2 (colony 2) (Sweet Road)	Low	Low	Low	Medium	Low	Low	High	Low	Low
United States	New York	Onondaga	Green Pond	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	New York	Onondaga	West White Lake	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	New York	Onondaga	Whiskey Hollow	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	New York	Onondaga	East White Lake	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	New York	Madison	Horseshoe Gorge (CF colony 2)	Medium	Medium	High	High	Medium	Medium	High	Medium	Low
United States	New York	Madison	Powerline Ravine (Chips Trail) (CF colony 3)	Low	Medium	High	High	Medium	Medium	High	Medium	Low
United States	New York	Madison	Stairway Talus (Falls / Gorge Trail) (CF colony1)	Low	High	High	High	Medium	Medium	High	Medium	Low
United States	New York	Madison	Munnsville [should this be 1 and 2?]	Low	Medium		High	Low	High	High	Medium	Low
United States	New York	Madison	Perryville Falls	Low	Low		High	Low	High	High	Medium	Low
United States	Tennessee	Marion	Kimball	Low	Low	Low	High	High	Low	Medium	Low	Low
United States	Tennessee	Roane	Post Oak Springs	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	Tennessee	Cumberland	Grassy Cove	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Alabama	Morgan	Newsome Sinks	Low	Medium	High	High	High	High	High	Medium	Low
United States	Alabama	Jackson	Fern Cave/Morgue Pit	Extirpated	Extirpated	Extirpated	High	High	High	High	Extirpated	High
Canada	Ontario	Grey	Aberdeen	Medium				Low		High	Medium	High
Canada	Ontario	Bruce	Adamsville 2.5 km NNW	Medium				Low		High	Medium	High
Canada	Ontario	Grey	Annan 2.4 km SE	Medium				Low		High	Medium	High
Canada	Ontario	Bruce	Barrow Bay South ANSI					Low		High	Unknown	High
Canada	Ontario	Bruce	Bass Lake Escarpment	Medium				Medium		High	Medium	High
Canada	Ontario	Grey	Bayview Escarpment	High	High			Medium		High	High	Medium
Canada	Ontario	Grey	Beaver Valley - Upper	Medium				Low		High	Medium	Medium
Canada	Ontario	Grey	Beaver Valley - West Slope					Low		High	Unknown	High
Canada	Ontario	Grey	Bognor NE	High				Low		High	High	High
Canada	Ontario	Grey	Bognor SW	High				Low		High	High	Medium
Canada	Ontario	Bruce	Boundary Bluffs Bruce Trail					Low		High	Unknown	High
Canada	Ontario	Bruce	Cape Croker - Malcom Bluff	Medium	Low			Low		High	Medium	High
Canada	Ontario	Bruce	Cape Croker - Sydney Bluff	Medium				Low		High	Medium	Medium
Canada	Ontario	Bruce	Cape Dundas	Medium				Low		High	Medium	High
Canada	Ontario	Grey	Castle Glen	Medium				Low		High	Medium	High
Canada	Ontario	Grey	Castle Glen SE	Low				Low		High	Low	High
Canada	Ontario	Grey	Chatsworth 3km South	Low	Medium			Medium		High	Medium	Medium
Canada	Ontario	Grey	Chatsworth L9 Con2	Low				Low		High	Low	High
Canada	Ontario	Bruce	Clark's Corner	High	High			Low		High	High	Low
Canada	Ontario	Bruce	Colpoys Bay					Low		High	Unknown	High
Canada	Ontario	Grey	Cruikshank 2 km NE					Low		High	Unknown	High
Canada	Ontario	Simcoe	Devil's Glen	Medium	Low			Low	Low	High	Medium	Low
Canada	Ontario	Grey	Duncan Escarpment PNR	Medium				Low		High	Medium	High
Canada	Ontario	Grey	Duncan Lake South	Medium	Low			Low		High	Medium	High
Canada	Ontario	Grey	Duntroon W Escarpment	Low				Low		High	Low	High
Canada	Ontario	Grey	Durham 3.6 km ENE	Low				Low		High	Low	High
Canada	Ontario	Grey	Durham 5 km SE	Medium				Low		High	Medium	High
Canada	Ontario	Grey	E of Desboro	Medium				Low		High	Medium	Medium
Canada	Ontario	Grey	E of Desboro - Klondike	Low	Low			Low		High	Low	Medium
Canada	Ontario	Grey	East Wiarton Upland Woods	Medium				Low		High	Medium	High
Canada	Ontario	Grey	Feversham Gorge	Medium				Medium		High	Medium	High
Canada	Ontario	Grey	Gibraltar					Low		High	Unknown	High
Canada	Ontario	Bruce	Greenock 2 km SW					Low		High	Unknown	High
Canada	Ontario	Grey	Griersville SE					Low		High	Unknown	Medium
Canada	Ontario	Grey	Hepworth 1.5 km NE	Medium				Low		High	Medium	High
Canada	Ontario	Bruce	Hope Bay 1.7 km SW	Medium				Low		High	Medium	Medium
Canada	Ontario	Bruce	Hope Bay Cathedral Woods	High				Low		High	High	High
Canada	Ontario	Bruce	Hope Bay PNR/ANSI	High				Low		High	High	High
Canada	Ontario	Grey	Indian Creek Mgt Area 2.5 km SE Lindenwood	High				Low		High	High	High
Canada	Ontario	Grey	Ingilis Falls	Medium		Medium		Medium		High	Medium	Medium

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Irish Block	Low				Low		High	Low	High
Canada	Ontario	Grey	Irish Block 2 km NW	Low				Low		High	Low	Medium
Canada	Ontario	Bruce	Kemble Mountain	High	Low			Medium		High	Medium	Medium
Canada	Ontario	Grey	Kimberley Bruce Trail	Low				Low		High	Low	High
Canada	Ontario	Grey	Kimberley Creek	Medium				Low		High	Medium	High
Canada	Ontario	Grey	Kinghurst	Medium	Low			Medium	Low	High	Low	Low
Canada	Ontario	Grey	Kolapore Escarpment	High				Low		High	High	High
Canada	Ontario	Grey	Kolapore Swamp East					Medium		High	Unknown	Medium
Canada	Ontario	Grey	Kolapore Upland Mgt Area (SE)	Medium	Low			Medium		High	Medium	Medium
Canada	Ontario	Grey	Lady Bank 2 km WSW					Low		High	Unknown	High
Canada	Ontario	Bruce	Lake Charles 1 km S	Medium				Low		High	Medium	High
Canada	Ontario	Bruce	Lake Charles 2 km E					Low		High	Unknown	Medium
Canada	Ontario	Grey	Lily Oak Forest	High	Low			Low	Low	High	Medium	Low
Canada	Ontario	Grey	Lindenwood SW	Low				Low		High	Low	Medium
Canada	Ontario	Bruce	Lion's Head North	Low				Medium		High	Low	High
Canada	Ontario	Bruce	Lion's Head South	Low				Low		High	Low	Medium
Canada	Ontario	Grey	Little Germany Management Area	Medium				Medium		High	Medium	Medium
Canada	Ontario	Grey	Massie Hills Management Area					Low		High	Unknown	High
Canada	Ontario	Grey	McIver Side Road	Medium				Low		High	Medium	High
Canada	Ontario	Grey	McNab Lake	High				Medium		High	High	High
Canada	Ontario	Grey	Minniehill SSE	Low				Low		High	Low	Medium
Canada	Ontario	Dufferin	Mono Cliffs PP	High	High			Medium		High	High	Low
Canada	Ontario	Grey	Mountain Lake Fen	High				Low		High	High	High
Canada	Ontario	Halton	Mt. Nemo	Low	Medium	Low		Medium		High	Low	Low
Canada	Ontario	Grey	Mud Creek East			Medium		Low		High	Unknown	Medium
Canada	Ontario	Grey	Mud Creek North	Medium				Medium		High	Medium	High
Canada	Ontario	Grey	Mud Creek South/Shouldice ANSI	High	Low			Low	Low	High	Medium	High
Canada	Ontario	Simcoe	Noisy River PP	High				Medium		High	High	Medium
Canada	Ontario	Simcoe	Nottawasaga Lookout	Low				Low		High	Low	Medium
Canada	Ontario	Simcoe	Nottawasaga South					Low		High	Unknown	Medium
Canada	Ontario	Simcoe	Osler Bluff	High	Low			Low	Low	High	Medium	Low
Canada	Ontario	Bruce	Owen Sound 4.7 km NW					Low		High	Unknown	High
Canada	Ontario	Grey	Owen Sound Rifle Range	High				Low		High	High	High
Canada	Ontario	Grey	Owen Sound South					Low		High	Unknown	Medium
Canada	Ontario	Grey	Owen Sound Southeast	Low				Low		High	Low	High
Canada	Ontario	Bruce	Park Head	High				Low		High	High	Medium
Canada	Ontario	Grey	Pottawatomi CA	Medium		Low		Medium		High	Medium	Medium
Canada	Ontario	Grey	Pretty River PP	Low				Medium		High	Low	High
Canada	Ontario	Bruce	Purple Valley	High	High			Low	Low	High	High	Low
Canada	Ontario	Grey	Rob Roy Management Area	Medium				Medium		High	Medium	High
Canada	Ontario	Grey	Rob Roy NE					Low		High	Unknown	High
Canada	Ontario	Grey	Robson Lakes					Low		High	Unknown	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Rockford 3.5 km SW	Low				Low		High	Low	High
Canada	Ontario	Grey	Rocklyn Creek Valley East	Medium				Medium		High	Medium	High
Canada	Ontario	Grey	Rocklyn Creek Valley West					Medium		High	Unknown	High
Canada	Ontario	Grey	Rocky Saugeen East	Medium				Low		High	Medium	High
Canada	Ontario	Grey	Rocky Saugeen South	Medium				Low		High	Medium	High
Canada	Ontario	Bruce	Rush Cove Corner	High				Low		High	High	High
Canada	Ontario	Halton	Scotsdale Farm					Medium		High	Unknown	Medium
Canada	Ontario	Bruce	SE Greenock					Low		High	Unknown	High
Canada	Ontario	Grey	Shallow Lake 2.8 km NNW	Low	Low			Low	Low	High	Low	High
Canada	Ontario	Grey	Shouldice Forest/The Glen	High				Low	Low	High	High	High
Canada	Ontario	Grey	Skinner's Bluff	High				Medium		High	High	Medium
Canada	Ontario	Grey	Slough of Despond	Medium				Medium		High	Medium	High
Canada	Ontario	Grey	Talisman Ski Area W of Kimberley	Low				Low		High	Low	High
Canada	Ontario	Bruce	Teeswater SE on Teeswater River					Low		High	Unknown	High
Canada	Ontario	Grey	Telfer Creek	Medium				Low		High	Medium	High
Canada	Ontario	Grey	Vandeleur	Medium				Low		High	Medium	Medium
Canada	Ontario	Dufferin	Violet Hill - Mono Cliffs North	Medium				Low		High	Medium	Medium
Canada	Ontario	Simcoe	Walker Quarry SW of Duntroon	High				Low		High	High	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area NE					Low		High	Unknown	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area SW					Low		High	Unknown	High
Canada	Ontario	Grey	Walter's Falls 3.5 km ESE					Low		High	Unknown	Medium
Canada	Ontario	Grey	West Rocks Management Area	Medium				Medium		High	Medium	High
Canada	Ontario	Peel	Wildwood Manor Ranch	Low				Low		High	Low	High
Canada	Ontario	Grey	Williams Lake 1 km E					Low		High	Unknown	High
Canada	Ontario	Grey	Williamsford Bridge 2.2 km					Low		High	Unknown	High
Canada	Ontario	Grey	Woodford 2.3 km NNW	High				Low		High	High	Medium
Canada	Ontario	Grey	Woodford W Bruce Trail	Medium				Low		High	Medium	High
Canada	Ontario	Bruce	Lindsay Tract	Low				Low		High	Low	Medium
Canada	Ontario	Bruce	Miller Lake	Low				Low		High	Low	Medium
Canada	Ontario	Bruce	W of Issac Lake	Low				Low		High	Low	Medium
Canada	Ontario	Grey	Red Wing	Extirpated				Low		High	Extirpated	High
Canada	Ontario	Bruce	Barrow Bay Village 3.2 km S	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Grey	Traverston Creek Village	Extirpated				Low		High	Extirpated	High
Canada	Ontario	Grey	Mulock 7 miles S	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Peel	Inglewood Slope	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Peel	Credit Forks	Extirpated				Medium		High	Extirpated	High
Canada	Ontario	Grey	Near Scenic Caves E Banks	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Simcoe	Stayner	Extirpated				Low		High	Extirpated	High
Canada	Ontario	Halton	Milton Heights	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Halton	Halton Forest North	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Grey	McKinney's Hill/Nottawasaga Bluffs CA	Extirpated				Low	Low	High	Extirpated	High
Canada	Ontario	Peel	Caledon Mountain Slope Forest	Extirpated				Low	Low	High	Extirpated	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Bruce	Between Boat and Spry Lake Bluewater Outdoor Center	Extirpated				Low		High	Extirpated	High
Canada	Ontario	Grey	Jones's Falls					Medium		High	Historical	High
Canada	Ontario	Grey	Wiarton area					Low		High	Historical	High
Canada	Ontario	Grey	Saugeen River					Low		High	Historical	High
Canada	Ontario	Bruce	1-1.5 Miles E Stokes Bay					Low		High	Historical	High
Canada	Ontario	Grey	Hayward Falls, Rocky Saugeen River					Low		High	Historical	High
Canada	Ontario	Grey	5 KM S Singhampton					Low		High	Historical	High
Canada	Ontario	Simcoe	East of Edward Lake					Low		High	Historical	High
Canada	Ontario	Grey	1 Mile E Eugenia					Low		High	Historical	High
Canada	Ontario	Grey	3 Mile E Eugenia					Low		High	Historical	High
Canada	Ontario	Grey	6 - 7 KM NE Hepworth					Low		High	Historical	High
Canada	Ontario	Grey	3.5 KM W Goring					Low		High	Historical	High

Scenerio 1 (50+ years)

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Michigan	Mackinac	Scherer (Hill Lake SW)	High		High	Medium	High	Medium	High	High	Low
United States	Michigan	Mackinac	Hiawatha (Hill Lake E)	High		High	Medium	High	Medium	High	High	Low
United States	Michigan	Mackinac	Pipeline	Low	Low	Medium	Low	Medium	Medium	High	Low	Low
United States	Michigan	Mackinac	NW of East Lake (Carp River - North Branch)	Medium	Medium	High	Medium	High	High	High	High	Low
United States	Michigan	Mackinac	SE of East Lake (East Lake Rd)	High	Medium	High	Low	Medium	Medium	High	Medium	Low
United States	Michigan	Mackinac	East Lake	Low	Low	High	Medium	High	High	High	Medium	Low
United States	Michigan	Mackinac	SW of East Lake (Sugar Camp)	Medium	Low	High	Medium	High	High	High	Medium	Low
United States	Michigan	Mackinac	Taylor Creek	High	Medium	High	Medium	High	High	High	High	Low
United States	Michigan	Mackinac	Gryke Site	Low	Low	High	Medium	High	High	High	Medium	Low
United States	Michigan	Mackinac	Piehler Site	Extirpated	Extirpated	Extirpated	Medium	High	High	High	Extirpated	Low
United States	Michigan	Mackinac	Cline Site	Extirpated	Extirpated	Extirpated	Medium	High	High	High	Extirpated	Low
United States	Michigan	Mackinac	Hill Lake SE	High		High	Medium	High	High	High	High	High
United States	Michigan	Chippewa	Trout Lake	Extirpated	Extirpated	Extirpated	Medium	High	High	High	Extirpated	Low
United States	New York	Onondaga	Lower Basin (colony 1)	Medium	High	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Onondaga	Dead End Ravine (colony 2)	High	Medium	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Onondaga	Grand Canyon (colony 3)	High	High	High	Medium	Medium	Medium	Medium	High	Low
United States	New York	Onondaga	Long Ravine (colony 4)	Low	Low	Medium	Medium	Medium	Medium	Medium	Low	Low
United States	New York	Onondaga	Sentinel Basin (colony 5)	High	High	High	Medium	Medium	Medium	Medium	High	Low
United States	New York	Onondaga	*Sentinel Basin 2 (colony 5 planted)	Extirpated	Extirpated	Extirpated	Low	Medium	Medium	Medium	Extirpated	Low
United States	New York	Onondaga	West Green Lake (Glacier Lake) (colony 6)	Low	Medium	Medium	Low	Medium	Medium	Medium	Medium	Low
United States	New York	Onondaga	*Twin Basins (planted)	Low		Medium	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Onondaga	Rock Cut Gorge	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	Low
United States	New York	Onondaga	Split Rock	Medium	Medium	High	Medium	Low	Low	Medium	Medium	Low
United States	New York	Onondaga	*Split Rock 2 (planted)	Extirpated	Extirpated	Extirpated	Medium	Low	Medium	Medium	Extirpated	Low
United States	New York	Onondaga	Rams Gulch	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	Low
United States	New York	Onondaga	Evergreen Lake 1 (colony 1) (Rock Face Gorge)	Low	Medium	Medium	Medium	Low	Medium	Medium	Medium	Low
United States	New York	Onondaga	Evergreen Lake 2 (colony 2) (Sweet Road)	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	Low
United States	New York	Onondaga	Green Pond	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
United States	New York	Onondaga	West White Lake	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
United States	New York	Onondaga	Whiskey Hollow	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
United States	New York	Onondaga	East White Lake	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
United States	New York	Madison	Horseshoe Gorge (CF colony 2)	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Madison	Powerline Ravine (Chips Trail) (CF colony 3)	Low	Medium	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Madison	Stairway Talus (Falls / Gorge Trail) (CF colony1)	Low	High	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Madison	Munnsville [should this be 1 and 2?]	Low	Medium		Medium	Low	High	Medium	Medium	Low
United States	New York	Madison	Perryville Falls	Low	Low		Medium	Low	High	Medium	Low	Low
United States	Tennessee	Marion	Kimball	Extirpated	Extirpated	Extirpated	High	High	Low	Medium	Extirpated	Low
United States	Tennessee	Roane	Post Oak Springs	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	Tennessee	Cumberland	Grassy Cove	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Alabama	Morgan	Newsome Sinks	Low	Medium	High	High	High	High	High	Medium	Low
United States	Alabama	Jackson	Fern Cave/Morgue Pit	Extirpated	Extirpated	Extirpated	High	High	High	High	Extirpated	High
Canada	Ontario	Grey	Aberdeen	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Bruce	Adamsville 2.5 km NNW	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Annan 2.4 km SE	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Bruce	Barrow Bay South ANSI				Low	Low		Medium	Unknown	High
Canada	Ontario	Bruce	Bass Lake Escarpment	Medium			Low	Medium		Medium	Medium	High
Canada	Ontario	Grey	Bayview Escarpment	High	High		Low	Medium		Medium	High	Medium
Canada	Ontario	Grey	Beaver Valley - Upper	Medium			Low	Low		Medium	Medium	Medium
Canada	Ontario	Grey	Beaver Valley - West Slope				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Bognor NE	High			Low	Low		Medium	High	High
Canada	Ontario	Grey	Bognor SW	High			Low	Low		Medium	High	Medium
Canada	Ontario	Bruce	Boundary Bluffs Bruce Trail				Low	Low		Medium	Unknown	High
Canada	Ontario	Bruce	Cape Croker - Malcom Bluff	Medium	Low		Low	Low		Medium	Medium	High
Canada	Ontario	Bruce	Cape Croker - Sydney Bluff	Medium			Low	Low		Medium	Medium	Medium
Canada	Ontario	Bruce	Cape Dundas	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Castle Glen	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Castle Glen SE	Extirpated	Extirpated	Extirpated	Low	Low		Medium	Low	High
Canada	Ontario	Grey	Chatsworth 3km South	Extirpated	Extirpated	Extirpated	Low	Medium		Medium	Medium	Medium
Canada	Ontario	Grey	Chatsworth L9 Con2	Low			Low	Low		Medium	Low	High
Canada	Ontario	Bruce	Clark's Corner	High	High		Low	Low		Medium	High	Low
Canada	Ontario	Bruce	Colpoys Bay				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Cruikshank 2 km NE				Low	Low		Medium	Unknown	High
Canada	Ontario	Simcoe	Devil's Glen	Medium	Low		Low	Low	Low	Medium	Medium	Low
Canada	Ontario	Grey	Duncan Escarpment PNR	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Duncan Lake South	Medium	Low		Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Duntroon W Escarpment	Low			Low	Low		Medium	Low	High
Canada	Ontario	Grey	Durham 3.6 km ENE	Low			Low	Low		Medium	Low	High
Canada	Ontario	Grey	Durham 5 km SE	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	E of Desboro	Medium			Low	Low		Medium	Medium	Medium
Canada	Ontario	Grey	E of Desboro - Klondike	Low	Low		Low	Low		Medium	Low	Medium
Canada	Ontario	Grey	East Wiarton Upland Woods	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Feversham Gorge	Medium			Low	Medium		Medium	Medium	High
Canada	Ontario	Grey	Gibraltar				Low	Low		Medium	Unknown	High
Canada	Ontario	Bruce	Greenock 2 km SW				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Griersville SE				Low	Low		Medium	Unknown	Medium
Canada	Ontario	Grey	Hepworth 1.5 km NE	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Bruce	Hope Bay 1.7 km SW	Medium			Low	Low		Medium	Medium	Medium
Canada	Ontario	Bruce	Hope Bay Cathedral Woods	High			Low	Low		Medium	High	High
Canada	Ontario	Bruce	Hope Bay PNR/ANSI	High			Low	Low		Medium	High	High
Canada	Ontario	Grey	Indian Creek Mgt Area 2.5 km SE Lindenwood	High			Low	Low		Medium	High	High
Canada	Ontario	Grey	Ingilis Falls	Medium		Medium	Low	Medium		Medium	Medium	Medium

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Irish Block	Low			Low	Low		Medium	Low	High
Canada	Ontario	Grey	Irish Block 2 km NW	Low			Low	Low		Medium	Low	Medium
Canada	Ontario	Bruce	Kemble Mountain	High	Low		Low	Medium		Medium	Medium	Medium
Canada	Ontario	Grey	Kimberley Bruce Trail	Extirpated	Extirpated	Extirpated	Low	Low		Medium	Low	High
Canada	Ontario	Grey	Kimberley Creek	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Kinghurst	Medium	Low		Low	Medium	Low	Medium	Low	Low
Canada	Ontario	Grey	Kolapore Escarpment	High			Low	Low		Medium	High	High
Canada	Ontario	Grey	Kolapore Swamp East				Low	Medium		Medium	Unknown	Medium
Canada	Ontario	Grey	Kolapore Upland Mgt Area (SE)	Medium	Low		Low	Medium		Medium	Medium	Medium
Canada	Ontario	Grey	Lady Bank 2 km WSW				Low	Low		Medium	Unknown	High
Canada	Ontario	Bruce	Lake Charles 1 km S	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Bruce	Lake Charles 2 km E				Low	Low		Medium	Unknown	Medium
Canada	Ontario	Grey	Lily Oak Forest	High	Low		Low	Low	Low	Medium	Medium	Low
Canada	Ontario	Grey	Lindenwood SW	Low			Low	Low		Medium	Low	Medium
Canada	Ontario	Bruce	Lion's Head North	Extirpated	Extirpated	Extirpated	Low	Medium		Medium	Low	High
Canada	Ontario	Bruce	Lion's Head South	Low			Low	Low		Medium	Low	Medium
Canada	Ontario	Grey	Little Germany Management Area	Medium			Low	Medium		Medium	Medium	Medium
Canada	Ontario	Grey	Massie Hills Management Area				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	McIver Side Road	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	McNab Lake	High			Low	Medium		Medium	High	High
Canada	Ontario	Grey	Minniehill SSE	Low			Low	Low		Medium	Low	Medium
Canada	Ontario	Dufferin	Mono Cliffs PP	High	High		Low	Medium		Medium	High	Low
Canada	Ontario	Grey	Mountain Lake Fen	High			Low	Low		Medium	High	High
Canada	Ontario	Halton	Mt. Nemo	Low	Medium	Low	Low	Medium		Medium	Low	Low
Canada	Ontario	Grey	Mud Creek East			Medium	Low	Low		Medium	Unknown	Medium
Canada	Ontario	Grey	Mud Creek North	Medium			Low	Medium		Medium	Medium	High
Canada	Ontario	Grey	Mud Creek South/Shouldice ANSI	High	Low		Low	Low	Low	Medium	Medium	High
Canada	Ontario	Simcoe	Noisy River PP	High			Low	Medium		Medium	High	Medium
Canada	Ontario	Simcoe	Nottawasaga Lookout	Low			Low	Low		Medium	Low	Medium
Canada	Ontario	Simcoe	Nottawasaga South				Low	Low		Medium	Unknown	Medium
Canada	Ontario	Simcoe	Osler Bluff	High	Low		Low	Low	Low	Medium	Medium	Low
Canada	Ontario	Bruce	Owen Sound 4.7 km NW				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Owen Sound Rifle Range	High			Low	Low		Medium	High	High
Canada	Ontario	Grey	Owen Sound South				Low	Low		Medium	Unknown	Medium
Canada	Ontario	Grey	Owen Sound Southeast	Low			Low	Low		Medium	Low	High
Canada	Ontario	Bruce	Park Head	High			Low	Low		Medium	High	Medium
Canada	Ontario	Grey	Pottawatomi CA	Medium		Low	Low	Medium		Medium	Medium	Medium
Canada	Ontario	Grey	Pretty River PP	Low			Low	Medium		Medium	Low	High
Canada	Ontario	Bruce	Purple Valley	High	High		Low	Low	Low	Medium	High	Low
Canada	Ontario	Grey	Rob Roy Management Area	Medium			Low	Medium		Medium	Medium	High
Canada	Ontario	Grey	Rob Roy NE				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Robson Lakes				Low	Low		Medium	Unknown	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Rockford 3.5 km SW	Low			Low	Low		Medium	Low	High
Canada	Ontario	Grey	Rocklyn Creek Valley East	Medium			Low	Medium		Medium	Medium	High
Canada	Ontario	Grey	Rocklyn Creek Valley West				Low	Medium		Medium	Unknown	High
Canada	Ontario	Grey	Rocky Saugeen East	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Rocky Saugeen South	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Bruce	Rush Cove Corner	High			Low	Low		Medium	High	High
Canada	Ontario	Halton	Scotsdale Farm				Low	Medium		Medium	Unknown	Medium
Canada	Ontario	Bruce	SE Greenock				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Shallow Lake 2.8 km NNW	Low	Low		Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Shouldice Forest/The Glen	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Grey	Skinner's Bluff	High			Low	Medium		Medium	High	Medium
Canada	Ontario	Grey	Slough of Despond	Medium			Low	Medium		Medium	Medium	High
Canada	Ontario	Grey	Talisman Ski Area W of Kimberley	Low			Low	Low		Medium	Low	High
Canada	Ontario	Bruce	Teeswater SE on Teeswater River				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Telfer Creek	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Grey	Vandeleur	Medium			Low	Low		Medium	Medium	Medium
Canada	Ontario	Dufferin	Violet Hill - Mono Cliffs North	Medium			Low	Low		Medium	Medium	Medium
Canada	Ontario	Simcoe	Walker Quarry SW of Duntroon	High			Low	Low		Medium	High	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area NE				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area SW				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Walter's Falls 3.5 km ESE				Low	Low		Medium	Unknown	Medium
Canada	Ontario	Grey	West Rocks Management Area	Medium			Low	Medium		Medium	Medium	High
Canada	Ontario	Peel	Wildwood Manor Ranch	Low			Low	Low		Medium	Low	High
Canada	Ontario	Grey	Williams Lake 1 km E				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Williamsford Bridge 2.2 km				Low	Low		Medium	Unknown	High
Canada	Ontario	Grey	Woodford 2.3 km NNW	High			Low	Low		Medium	High	Medium
Canada	Ontario	Grey	Woodford W Bruce Trail	Medium			Low	Low		Medium	Medium	High
Canada	Ontario	Bruce	Lindsay Tract	Low			Low	Low		Medium	Low	Medium
Canada	Ontario	Bruce	Miller Lake	Extirpated	Extirpated	Extirpated	Low	Low		Medium	Low	Medium
Canada	Ontario	Bruce	W of Issac Lake	Low			Low	Low		Medium	Low	Medium
Canada	Ontario	Grey	Red Wing	Extirpated	Extirpated	Extirpated	Low	Low		Medium	Extirpated	High
Canada	Ontario	Bruce	Barrow Bay Village 3.2 km S	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Grey	Traverston Creek Village	Extirpated	Extirpated	Extirpated	Low	Low		Medium	Extirpated	High
Canada	Ontario	Grey	Mulock 7 miles S	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Peel	Inglewood Slope	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Peel	Credit Forks	Extirpated	Extirpated	Extirpated	Low	Medium		Medium	Extirpated	High
Canada	Ontario	Grey	Near Scenic Caves E Banks	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Simcoe	Stayner	Extirpated	Extirpated	Extirpated	Low	Low		Medium	Extirpated	High
Canada	Ontario	Halton	Milton Heights	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Halton	Halton Forest North	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Grey	McKinney's Hill/Nottawasaga Bluffs CA	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Peel	Caledon Mountain Slope Forest	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Bruce	Between Boat and Spry Lake Bluewater Outdoor Center	Extirpated	Extirpated	Extirpated	Low	Low		Medium	Extirpated	High
Canada	Ontario	Grey	Jones's Falls				Low	Medium		Medium	Historical	High
Canada	Ontario	Grey	Wiarton area				Low	Low		Medium	Historical	High
Canada	Ontario	Grey	Saugeen River				Low	Low		Medium	Historical	High
Canada	Ontario	Bruce	1-1.5 Miles E Stokes Bay				Low	Low		Medium	Historical	High
Canada	Ontario	Grey	Hayward Falls, Rocky Saugeen River				Low	Low		Medium	Historical	High
Canada	Ontario	Grey	5 KM S Singhampton				Low	Low		Medium	Historical	High
Canada	Ontario	Simcoe	East of Edward Lake				Low	Low		Medium	Historical	High
Canada	Ontario	Grey	1 Mile E Eugenia				Low	Low		Medium	Historical	High
Canada	Ontario	Grey	3 Mile E Eugenia				Low	Low		Medium	Historical	High
Canada	Ontario	Grey	6 - 7 KM NE Hepworth				Low	Low		Medium	Historical	High
Canada	Ontario	Grey	3.5 KM W Goring				Low	Low		Medium	Historical	High

Scenario 2 (30 to 50 years)

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Michigan	Mackinac	Scherer (Hill Lake SW)	High		High	Medium	High	Medium	High	High	Low
United States	Michigan	Mackinac	Hiawatha (Hill Lake E)	High		High	Medium	High	Medium	High	High	Low
United States	Michigan	Mackinac	Pipeline	Low	Low	Medium	Low	Medium	Medium	High	Low	Low
United States	Michigan	Mackinac	NW of East Lake (Carp River - North Branch)	Medium	Medium	High	Medium	High	High	High	High	Low
United States	Michigan	Mackinac	SE of East Lake (East Lake Rd)	High	Medium	High	Low	Medium	Medium	High	Medium	Low
United States	Michigan	Mackinac	East Lake	Low	Low	High	Medium	High	High	High	Medium	Low
United States	Michigan	Mackinac	SW of East Lake (Sugar Camp)	Medium	Low	High	Medium	High	High	High	Medium	Low
United States	Michigan	Mackinac	Taylor Creek	High	Medium	High	Medium	High	High	High	High	Low
United States	Michigan	Mackinac	Gryke Site	Low	Low	High	Medium	High	High	High	Medium	Low
United States	Michigan	Mackinac	Piehler Site	Extirpated	Extirpated	Extirpated	Medium	High	High	High	Extirpated	Low
United States	Michigan	Mackinac	Cline Site	Extirpated	Extirpated	Extirpated	Medium	High	High	High	Extirpated	Low
United States	Michigan	Mackinac	Hill Lake SE	High		High	Medium	High	High	High	High	High
United States	Michigan	Chippewa	Trout Lake	Extirpated	Extirpated	Extirpated	Medium	High	High	High	Extirpated	Low
United States	New York	Onondaga	Lower Basin (colony 1)	Medium	High	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Onondaga	Dead End Ravine (colony 2)	High	Medium	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Onondaga	Grand Canyon (colony 3)	High	High	High	Medium	Medium	Medium	Medium	High	Low
United States	New York	Onondaga	Long Ravine (colony 4)	Low	Low	Medium	Medium	Medium	Medium	Medium	Low	Low
United States	New York	Onondaga	Sentinel Basin (colony 5)	High	High	High	Medium	Medium	Medium	Medium	High	Low
United States	New York	Onondaga	*Sentinel Basin 2 (colony 5 planted)	Extirpated	Extirpated	Extirpated	Low	Medium	Medium	Medium	Extirpated	Low
United States	New York	Onondaga	West Green Lake (Glacier Lake) (colony 6)	Low	Medium	Medium	Low	Medium	Medium	Medium	Medium	Low
United States	New York	Onondaga	*Twin Basins (planted)	Low		Medium	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Onondaga	Rock Cut Gorge	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	Low
United States	New York	Onondaga	Split Rock	Medium	Medium	High	Medium	Low	Low	Medium	Medium	Low
United States	New York	Onondaga	*Split Rock 2 (planted)	Extirpated	Extirpated	Extirpated	Medium	Low	Medium	Medium	Extirpated	Low
United States	New York	Onondaga	Rams Gulch	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	Low
United States	New York	Onondaga	Evergreen Lake 1 (colony 1) (Rock Face Gorge)	Low	Medium	Medium	Medium	Low	Medium	Medium	Medium	Low
United States	New York	Onondaga	Evergreen Lake 2 (colony 2) (Sweet Road)	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	Low
United States	New York	Onondaga	Green Pond	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
United States	New York	Onondaga	West White Lake	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
United States	New York	Onondaga	Whiskey Hollow	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
United States	New York	Onondaga	East White Lake	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
United States	New York	Madison	Horseshoe Gorge (CF colony 2)	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Madison	Powerline Ravine (Chips Trail) (CF colony 3)	Low	Medium	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Madison	Stairway Talus (Falls / Gorge Trail) (CF colony1)	Low	High	High	Medium	Medium	Medium	Medium	Medium	Low
United States	New York	Madison	Munnsville [should this be 1 and 2?]	Low	Medium		Medium	Low	High	Medium	Medium	Low
United States	New York	Madison	Perryville Falls	Low	Low		Medium	Low	High	Medium	Medium	Low
United States	Tennessee	Marion	Kimball	Extirpated	Extirpated	Extirpated	High	High	Low	Medium	Extirpated	Low
United States	Tennessee	Roane	Post Oak Springs	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	Tennessee	Cumberland	Grassy Cove	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Alabama	Morgan	Newsome Sinks	Low	Medium	High	High	High	High	High	Medium	Low
United States	Alabama	Jackson	Fern Cave/Morgue Pit	Extirpated	Extirpated	Extirpated	High	High	High	High	Extirpated	High
Canada	Ontario	Grey	Aberdeen	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Bruce	Adamsville 2.5 km NNW	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Annan 2.4 km SE	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Bruce	Barrow Bay South ANSI				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Bruce	Bass Lake Escarpment	Medium			Low	Medium	Low	Medium	Medium	High
Canada	Ontario	Grey	Bayview Escarpment	High	High		Low	Medium	Low	Medium	High	Medium
Canada	Ontario	Grey	Beaver Valley - Upper	Medium			Low	Low	Low	Medium	Medium	Medium
Canada	Ontario	Grey	Beaver Valley - West Slope				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Bognor NE	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Grey	Bognor SW	High			Low	Low	Low	Medium	High	Medium
Canada	Ontario	Bruce	Boundary Bluffs Bruce Trail				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Bruce	Cape Croker - Malcom Bluff	Medium	Low		Low	Low	Low	Medium	Medium	High
Canada	Ontario	Bruce	Cape Croker - Sydney Bluff	Medium			Low	Low	Low	Medium	Medium	Medium
Canada	Ontario	Bruce	Cape Dundas	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Castle Glen	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Castle Glen SE	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Chatsworth 3km South	Extirpated	Extirpated	Extirpated	Low	Medium	Low	Medium	Medium	Medium
Canada	Ontario	Grey	Chatsworth L9 Con2	Low			Low	Low	Low	Medium	Low	High
Canada	Ontario	Bruce	Clark's Corner	High	High		Low	Low	Low	Medium	High	Low
Canada	Ontario	Bruce	Colpoys Bay				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Cruikshank 2 km NE				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Simcoe	Devil's Glen	Medium	Low		Low	Low	Low	Medium	Medium	Low
Canada	Ontario	Grey	Duncan Escarpment PNR	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Duncan Lake South	Medium	Low		Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Duntroon W Escarpment	Low			Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Durham 3.6 km ENE	Low			Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Durham 5 km SE	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	E of Desboro	Medium			Low	Low	Low	Medium	Medium	Medium
Canada	Ontario	Grey	E of Desboro - Klondike	Low	Low		Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Grey	East Wiarton Upland Woods	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Feversham Gorge	Medium			Low	Medium	Low	Medium	Medium	High
Canada	Ontario	Grey	Gibraltar				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Bruce	Greenock 2 km SW				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Griersville SE				Low	Low	Low	Medium	Unknown	Medium
Canada	Ontario	Grey	Hepworth 1.5 km NE	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Bruce	Hope Bay 1.7 km SW	Medium			Low	Low	Low	Medium	Medium	Medium
Canada	Ontario	Bruce	Hope Bay Cathedral Woods	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Bruce	Hope Bay PNR/ANSI	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Grey	Indian Creek Mgt Area 2.5 km SE Lindenwood	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Grey	Ingilis Falls	Medium		Medium	Low	Medium	Low	Medium	Medium	Medium

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Irish Block	Low			Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Irish Block 2 km NW	Low			Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Bruce	Kemble Mountain	High	Low		Low	Medium	Low	Medium	Medium	Medium
Canada	Ontario	Grey	Kimberley Bruce Trail	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Kimberley Creek	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Kinghurst	Medium	Low		Low	Medium	Low	Medium	Low	Low
Canada	Ontario	Grey	Kolapore Escarpment	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Grey	Kolapore Swamp East				Low	Medium	Low	Medium	Unknown	Medium
Canada	Ontario	Grey	Kolapore Upland Mgt Area (SE)	Medium	Low		Low	Medium	Low	Medium	Medium	Medium
Canada	Ontario	Grey	Lady Bank 2 km WSW				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Bruce	Lake Charles 1 km S	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Bruce	Lake Charles 2 km E				Low	Low	Low	Medium	Unknown	Medium
Canada	Ontario	Grey	Lily Oak Forest	High	Low		Low	Low	Low	Medium	Medium	Low
Canada	Ontario	Grey	Lindenwood SW	Low			Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Bruce	Lion's Head North	Extirpated	Extirpated	Extirpated	Low	Medium	Low	Medium	Low	High
Canada	Ontario	Bruce	Lion's Head South	Low			Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Grey	Little Germany Management Area	Medium			Low	Medium	Low	Medium	Medium	Medium
Canada	Ontario	Grey	Massie Hills Management Area				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	McIver Side Road	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	McNab Lake	High			Low	Medium	Low	Medium	High	High
Canada	Ontario	Grey	Minniehill SSE	Low			Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Dufferin	Mono Cliffs PP	High	High		Low	Medium	Low	Medium	High	Low
Canada	Ontario	Grey	Mountain Lake Fen	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Halton	Mt. Nemo	Low	Medium	Low	Low	Medium	Low	Medium	Low	Low
Canada	Ontario	Grey	Mud Creek East			Medium	Low	Low	Low	Medium	Unknown	Medium
Canada	Ontario	Grey	Mud Creek North	Medium			Low	Medium	Low	Medium	Medium	High
Canada	Ontario	Grey	Mud Creek South/Shouldice ANSI	High	Low		Low	Low	Low	Medium	Medium	High
Canada	Ontario	Simcoe	Noisy River PP	High			Low	Medium	Low	Medium	High	Medium
Canada	Ontario	Simcoe	Nottawasaga Lookout	Low			Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Simcoe	Nottawasaga South				Low	Low	Low	Medium	Unknown	Medium
Canada	Ontario	Simcoe	Osler Bluff	High	Low		Low	Low	Low	Medium	Medium	Low
Canada	Ontario	Bruce	Owen Sound 4.7 km NW				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Owen Sound Rifle Range	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Grey	Owen Sound South				Low	Low	Low	Medium	Unknown	Medium
Canada	Ontario	Grey	Owen Sound Southeast	Low			Low	Low	Low	Medium	Low	High
Canada	Ontario	Bruce	Park Head	High			Low	Low	Low	Medium	High	Medium
Canada	Ontario	Grey	Pottawatomi CA	Medium		Low	Low	Medium	Low	Medium	Medium	Medium
Canada	Ontario	Grey	Pretty River PP	Low			Low	Medium	Low	Medium	Low	High
Canada	Ontario	Bruce	Purple Valley	High	High		Low	Low	Low	Medium	High	Low
Canada	Ontario	Grey	Rob Roy Management Area	Medium			Low	Medium	Low	Medium	Medium	High
Canada	Ontario	Grey	Rob Roy NE				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Robson Lakes				Low	Low	Low	Medium	Unknown	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Rockford 3.5 km SW	Low			Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Rocklyn Creek Valley East	Medium			Low	Medium	Low	Medium	Medium	High
Canada	Ontario	Grey	Rocklyn Creek Valley West				Low	Medium	Low	Medium	Unknown	High
Canada	Ontario	Grey	Rocky Saugeen East	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Rocky Saugeen South	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Bruce	Rush Cove Corner	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Halton	Scotsdale Farm				Low	Medium	Low	Medium	Unknown	Medium
Canada	Ontario	Bruce	SE Greenock				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Shallow Lake 2.8 km NNW	Low	Low		Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Shouldice Forest/The Glen	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Grey	Skinner's Bluff	High			Low	Medium	Low	Medium	High	Medium
Canada	Ontario	Grey	Slough of Despond	Medium			Low	Medium	Low	Medium	Medium	High
Canada	Ontario	Grey	Talisman Ski Area W of Kimberley	Low			Low	Low	Low	Medium	Low	High
Canada	Ontario	Bruce	Teeswater SE on Teeswater River				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Telfer Creek	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Grey	Vandeleur	Medium			Low	Low	Low	Medium	Medium	Medium
Canada	Ontario	Dufferin	Violet Hill - Mono Cliffs North	Medium			Low	Low	Low	Medium	Medium	Medium
Canada	Ontario	Simcoe	Walker Quarry SW of Duntroon	High			Low	Low	Low	Medium	High	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area NE				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area SW				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Walter's Falls 3.5 km ESE				Low	Low	Low	Medium	Unknown	Medium
Canada	Ontario	Grey	West Rocks Management Area	Medium			Low	Medium	Low	Medium	Medium	High
Canada	Ontario	Peel	Wildwood Manor Ranch	Low			Low	Low	Low	Medium	Low	High
Canada	Ontario	Grey	Williams Lake 1 km E				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Williamsford Bridge 2.2 km				Low	Low	Low	Medium	Unknown	High
Canada	Ontario	Grey	Woodford 2.3 km NNW	High			Low	Low	Low	Medium	High	Medium
Canada	Ontario	Grey	Woodford W Bruce Trail	Medium			Low	Low	Low	Medium	Medium	High
Canada	Ontario	Bruce	Lindsay Tract	Low			Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Bruce	Miller Lake	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Bruce	W of Issac Lake	Low			Low	Low	Low	Medium	Low	Medium
Canada	Ontario	Grey	Red Wing	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Bruce	Barrow Bay Village 3.2 km S	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Grey	Traverston Creek Village	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Grey	Mulock 7 miles S	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Peel	Inglewood Slope	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Peel	Credit Forks	Extirpated	Extirpated	Extirpated	Low	Medium	Low	Medium	Extirpated	High
Canada	Ontario	Grey	Near Scenic Caves E Banks	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Simcoe	Stayner	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Halton	Milton Heights	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Halton	Halton Forest North	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Grey	McKinney's Hill/Nottawasaga Bluffs CA	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Peel	Caledon Mountain Slope Forest	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Bruce	Between Boat and Spry Lake Bluewater Outdoor Center	Extirpated	Extirpated	Extirpated	Low	Low	Low	Medium	Extirpated	High
Canada	Ontario	Grey	Jones's Falls				Low	Medium	Low	Medium	Historical	High
Canada	Ontario	Grey	Wiarton area				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Grey	Saugeen River				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Bruce	1-1.5 Miles E Stokes Bay				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Grey	Hayward Falls, Rocky Saugeen River				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Grey	5 KM S Singhampton				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Simcoe	East of Edward Lake				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Grey	1 Mile E Eugenia				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Grey	3 Mile E Eugenia				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Grey	6 - 7 KM NE Hepworth				Low	Low	Low	Medium	Historical	High
Canada	Ontario	Grey	3.5 KM W Goring				Low	Low	Low	Medium	Historical	High

Scenario 2 (50+ years)

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Michigan	Mackinac	Scherer (Hill Lake SW)	High		High	Low	High	Medium	High	High	Low
United States	Michigan	Mackinac	Hiawatha (Hill Lake E)	High		High	Low	High	Medium	High	High	Low
United States	Michigan	Mackinac	Pipeline	Low	Low	Medium	Low	Medium	Medium	High	Low	Low
United States	Michigan	Mackinac	NW of East Lake (Carp River - North Branch)	Medium	Medium	High	Low	High	High	High	Medium	Low
United States	Michigan	Mackinac	SE of East Lake (East Lake Rd)	High	Medium	High	Low	Medium	Medium	High	Medium	Low
United States	Michigan	Mackinac	East Lake	Low	Low	High	Low	High	High	High	Medium	Low
United States	Michigan	Mackinac	SW of East Lake (Sugar Camp)	Medium	Low	High	Low	High	High	High	Medium	Low
United States	Michigan	Mackinac	Taylor Creek	High	Medium	High	Low	High	High	High	High	Low
United States	Michigan	Mackinac	Gryke Site	Extirpated	Extirpated	Extirpated	Low	High	High	High	Extirpated	Low
United States	Michigan	Mackinac	Piehler Site	Extirpated	Extirpated	Extirpated	Low	High	High	High	Extirpated	Low
United States	Michigan	Mackinac	Cline Site	Extirpated	Extirpated	Extirpated	Low	High	High	High	Extirpated	Low
United States	Michigan	Mackinac	Hill Lake SE	High		High	Low	High	High	High	High	High
United States	Michigan	Chippewa	Trout Lake	Extirpated	Extirpated	Extirpated	Low	High	High	High	Extirpated	Low
United States	New York	Onondaga	Lower Basin (colony 1)	Medium	High	High	Low	High	Low	High	Medium	Low
United States	New York	Onondaga	Dead End Ravine (colony 2)	High	Medium	High	Low	High	Low	High	Medium	Low
United States	New York	Onondaga	Grand Canyon (colony 3)	High	High	High	Low	High	Low	High	High	Low
United States	New York	Onondaga	Long Ravine (colony 4)	Low	Low	Medium	Low	High	Low	High	Low	Low
United States	New York	Onondaga	Sentinel Basin (colony 5)	High	High	High	Low	High	Low	High	High	Low
United States	New York	Onondaga	*Sentinel Basin 2 (colony 5 planted)	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	Low
United States	New York	Onondaga	West Green Lake (Glacier Lake) (colony 6)	Low	Medium	Medium	Low	High	Low	High	Medium	Low
United States	New York	Onondaga	*Twin Basins (planted)	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	Low
United States	New York	Onondaga	Rock Cut Gorge	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	Low
United States	New York	Onondaga	Split Rock	Medium	Medium	High	Low	High	Low	High	Medium	Low
United States	New York	Onondaga	*Split Rock 2 (planted)	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	Low
United States	New York	Onondaga	Rams Gulch	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	Low
United States	New York	Onondaga	Evergreen Lake 1 (colony 1) (Rock Face Gorge)	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	Low
United States	New York	Onondaga	Evergreen Lake 2 (colony 2) (Sweet Road)	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	Low
United States	New York	Onondaga	Green Pond	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	High
United States	New York	Onondaga	West White Lake	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	High
United States	New York	Onondaga	Whiskey Hollow	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	High
United States	New York	Onondaga	East White Lake	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	High
United States	New York	Madison	Horseshoe Gorge (CF colony 2)	Medium	Medium	High	Low	High	Low	High	Medium	Low
United States	New York	Madison	Powerline Ravine (Chips Trail) (CF colony 3)	Low	Medium	High	Low	High	Low	High	Medium	Low
United States	New York	Madison	Stairway Talus (Falls / Gorge Trail) (CF colony1)	Low	High	High	Low	High	Low	High	Medium	Low
United States	New York	Madison	Munnsville [should this be 1 and 2?]	Low	Medium		Low	High	Low	High	Medium	Low
United States	New York	Madison	Perryville Falls	Extirpated	Extirpated	Extirpated	Low	High	Low	High	Extirpated	Low
United States	Tennessee	Marion	Kimball	Extirpated	Extirpated	Extirpated	High	High	Low	Medium	Extirpated	Low
United States	Tennessee	Roane	Post Oak Springs	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
United States	Tennessee	Cumberland	Grassy Cove	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
United States	Alabama	Morgan	Newsome Sinks	Low	Medium	High	High	High	High	High	Medium	Low
United States	Alabama	Jackson	Fern Cave/Morgue Pit	Extirpated	Extirpated	Extirpated	High	High	High	High	Extirpated	High
Canada	Ontario	Grey	Aberdeen	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Bruce	Adamsville 2.5 km NNW	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Annan 2.4 km SE	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Bruce	Barrow Bay South ANSI				Low	Low	Low	High	Unknown	High
Canada	Ontario	Bruce	Bass Lake Escarpment	Medium			Low	Medium	Low	High	Medium	High
Canada	Ontario	Grey	Bayview Escarpment	High	High		Low	Medium	Low	High	High	Medium
Canada	Ontario	Grey	Beaver Valley - Upper	Medium			Low	Low	Low	High	Medium	Medium
Canada	Ontario	Grey	Beaver Valley - West Slope				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Bognor NE	High			Low	Low	Low	High	High	High
Canada	Ontario	Grey	Bognor SW	High			Low	Low	Low	High	High	Medium
Canada	Ontario	Bruce	Boundary Bluffs Bruce Trail				Low	Low	Low	High	Unknown	High
Canada	Ontario	Bruce	Cape Croker - Malcom Bluff	Medium	Low		Low	Low	Low	High	Medium	High
Canada	Ontario	Bruce	Cape Croker - Sydney Bluff	Medium			Low	Low	Low	High	Medium	Medium
Canada	Ontario	Bruce	Cape Dundas	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Castle Glen	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Castle Glen SE	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Low	High
Canada	Ontario	Grey	Chatsworth 3km South	Extirpated	Extirpated	Extirpated	Low	Medium	Low	High	Medium	Medium
Canada	Ontario	Grey	Chatsworth L9 Con2	Low			Low	Low	Low	High	Low	High
Canada	Ontario	Bruce	Clark's Corner	High	High		Low	Low	Low	High	High	Low
Canada	Ontario	Bruce	Colpoys Bay				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Cruikshank 2 km NE				Low	Low	Low	High	Unknown	High
Canada	Ontario	Simcoe	Devil's Glen	Medium	Low		Low	Low	Low	High	Medium	Low
Canada	Ontario	Grey	Duncan Escarpment PNR	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Duncan Lake South	Medium	Low		Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Duntroon W Escarpment	Low			Low	Low	Low	High	Low	High
Canada	Ontario	Grey	Durham 3.6 km ENE	Low			Low	Low	Low	High	Low	High
Canada	Ontario	Grey	Durham 5 km SE	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	E of Desboro	Medium			Low	Low	Low	High	Medium	Medium
Canada	Ontario	Grey	E of Desboro - Klondike	Low	Low		Low	Low	Low	High	Low	Medium
Canada	Ontario	Grey	East Wiarton Upland Woods	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Feversham Gorge	Medium			Low	Medium	Low	High	Medium	High
Canada	Ontario	Grey	Gibraltar				Low	Low	Low	High	Unknown	High
Canada	Ontario	Bruce	Greenock 2 km SW				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Griersville SE				Low	Low	Low	High	Unknown	Medium
Canada	Ontario	Grey	Hepworth 1.5 km NE	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Bruce	Hope Bay 1.7 km SW	Medium			Low	Low	Low	High	Medium	Medium
Canada	Ontario	Bruce	Hope Bay Cathedral Woods	High			Low	Low	Low	High	High	High
Canada	Ontario	Bruce	Hope Bay PNR/ANSI	High			Low	Low	Low	High	High	High
Canada	Ontario	Grey	Indian Creek Mgt Area 2.5 km SE Lindenwood	High			Low	Low	Low	High	High	High
Canada	Ontario	Grey	Ingilis Falls	Medium		Medium	Low	Medium	Low	High	Medium	Medium

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Irish Block	Low			Low	Low	Low	High	Low	High
Canada	Ontario	Grey	Irish Block 2 km NW	Low			Low	Low	Low	High	Low	Medium
Canada	Ontario	Bruce	Kemble Mountain	High	Low		Low	Medium	Low	High	Medium	Medium
Canada	Ontario	Grey	Kimberley Bruce Trail	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Low	High
Canada	Ontario	Grey	Kimberley Creek	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Kinghurst	Medium	Low		Low	Medium	Low	High	Low	Low
Canada	Ontario	Grey	Kolapore Escarpment	High			Low	Low	Low	High	High	High
Canada	Ontario	Grey	Kolapore Swamp East				Low	Medium	Low	High	Unknown	Medium
Canada	Ontario	Grey	Kolapore Upland Mgt Area (SE)	Medium	Low		Low	Medium	Low	High	Medium	Medium
Canada	Ontario	Grey	Lady Bank 2 km WSW				Low	Low	Low	High	Unknown	High
Canada	Ontario	Bruce	Lake Charles 1 km S	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Bruce	Lake Charles 2 km E				Low	Low	Low	High	Unknown	Medium
Canada	Ontario	Grey	Lily Oak Forest	High	Low		Low	Low	Low	High	Medium	Low
Canada	Ontario	Grey	Lindenwood SW	Low			Low	Low	Low	High	Low	Medium
Canada	Ontario	Bruce	Lion's Head North	Extirpated	Extirpated	Extirpated	Low	Medium	Low	High	Low	High
Canada	Ontario	Bruce	Lion's Head South	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Low	Medium
Canada	Ontario	Grey	Little Germany Management Area	Medium			Low	Medium	Low	High	Medium	Medium
Canada	Ontario	Grey	Massie Hills Management Area				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	McIver Side Road	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	McNab Lake	High			Low	Medium	Low	High	High	High
Canada	Ontario	Grey	Minniehill SSE	Low			Low	Low	Low	High	Low	Medium
Canada	Ontario	Dufferin	Mono Cliffs PP	High	High		Low	Medium	Low	High	High	Low
Canada	Ontario	Grey	Mountain Lake Fen	High			Low	Low	Low	High	High	High
Canada	Ontario	Halton	Mt. Nemo	Extirpated	Extirpated	Extirpated	Low	Medium	Low	High	Low	Low
Canada	Ontario	Grey	Mud Creek East			Medium	Low	Low	Low	High	Unknown	Medium
Canada	Ontario	Grey	Mud Creek North	Medium			Low	Medium	Low	High	Medium	High
Canada	Ontario	Grey	Mud Creek South/Shouldice ANSI	High	Low		Low	Low	Low	High	Medium	High
Canada	Ontario	Simcoe	Noisy River PP	High			Low	Medium	Low	High	High	Medium
Canada	Ontario	Simcoe	Nottawasaga Lookout	Low			Low	Low	Low	High	Low	Medium
Canada	Ontario	Simcoe	Nottawasaga South				Low	Low	Low	High	Unknown	Medium
Canada	Ontario	Simcoe	Osler Bluff	High	Low		Low	Low	Low	High	Medium	Low
Canada	Ontario	Bruce	Owen Sound 4.7 km NW				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Owen Sound Rifle Range	High			Low	Low	Low	High	High	High
Canada	Ontario	Grey	Owen Sound South				Low	Low	Low	High	Unknown	Medium
Canada	Ontario	Grey	Owen Sound Southeast	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Low	High
Canada	Ontario	Bruce	Park Head	High			Low	Low	Low	High	High	Medium
Canada	Ontario	Grey	Pottawatomi CA	Medium		Low	Low	Medium	Low	High	Medium	Medium
Canada	Ontario	Grey	Pretty River PP	Low			Low	Medium	Low	High	Low	High
Canada	Ontario	Bruce	Purple Valley	High	High		Low	Low	Low	High	High	Low
Canada	Ontario	Grey	Rob Roy Management Area	Medium			Low	Medium	Low	High	Medium	High
Canada	Ontario	Grey	Rob Roy NE				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Robson Lakes				Low	Low	Low	High	Unknown	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Grey	Rockford 3.5 km SW	Low			Low	Low	Low	High	Low	High
Canada	Ontario	Grey	Rocklyn Creek Valley East	Medium			Low	Medium	Low	High	Medium	High
Canada	Ontario	Grey	Rocklyn Creek Valley West				Low	Medium	Low	High	Unknown	High
Canada	Ontario	Grey	Rocky Saugeen East	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Rocky Saugeen South	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Bruce	Rush Cove Corner	High			Low	Low	Low	High	High	High
Canada	Ontario	Halton	Scotsdale Farm				Low	Medium	Low	High	Unknown	Medium
Canada	Ontario	Bruce	SE Greenock				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Shallow Lake 2.8 km NNW	Low	Low		Low	Low	Low	High	Low	High
Canada	Ontario	Grey	Shouldice Forest/The Glen	High			Low	Low	Low	High	High	High
Canada	Ontario	Grey	Skinner's Bluff	High			Low	Medium	Low	High	High	Medium
Canada	Ontario	Grey	Slough of Despond	Medium			Low	Medium	Low	High	Medium	High
Canada	Ontario	Grey	Talisman Ski Area W of Kimberley	Low			Low	Low	Low	High	Low	High
Canada	Ontario	Bruce	Teeswater SE on Teeswater River				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Telfer Creek	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Grey	Vandeleur	Medium			Low	Low	Low	High	Medium	Medium
Canada	Ontario	Dufferin	Violet Hill - Mono Cliffs North	Medium			Low	Low	Low	High	Medium	Medium
Canada	Ontario	Simcoe	Walker Quarry SW of Duntroon	High			Low	Low	Low	High	High	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area NE				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Walter's Creek Headwaters Area SW				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Walter's Falls 3.5 km ESE				Low	Low	Low	High	Unknown	Medium
Canada	Ontario	Grey	West Rocks Management Area	Medium			Low	Medium	Low	High	Medium	High
Canada	Ontario	Peel	Wildwood Manor Ranch	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Low	High
Canada	Ontario	Grey	Williams Lake 1 km E				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Williamsford Bridge 2.2 km				Low	Low	Low	High	Unknown	High
Canada	Ontario	Grey	Woodford 2.3 km NNW	High			Low	Low	Low	High	High	Medium
Canada	Ontario	Grey	Woodford W Bruce Trail	Medium			Low	Low	Low	High	Medium	High
Canada	Ontario	Bruce	Lindsay Tract	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Low	Medium
Canada	Ontario	Bruce	Miller Lake	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Low	Medium
Canada	Ontario	Bruce	W of Issac Lake	Low			Low	Low	Low	High	Low	Medium
Canada	Ontario	Grey	Red Wing	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Bruce	Barrow Bay Village 3.2 km S	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Grey	Traverston Creek Village	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Grey	Mulock 7 miles S	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Peel	Inglewood Slope	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Peel	Credit Forks	Extirpated	Extirpated	Extirpated	Low	Medium	Low	High	Extirpated	High
Canada	Ontario	Grey	Near Scenic Caves E Banks	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Simcoe	Stayner	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Halton	Milton Heights	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Halton	Halton Forest North	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Grey	McKinney's Hill/Nottawasaga Bluffs CA	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Peel	Caledon Mountain Slope Forest	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High

Country	State/Province	County	Population	Abundance Rank	Trend Rank	Reproduction Rank	Moisture Rank	Substrate Rank	Light Rank	Freeze/thaw buffer Rank	Rank	Uncertainty
Canada	Ontario	Bruce	Between Boat and Spry Lake Bluewater Outdoor Center	Extirpated	Extirpated	Extirpated	Low	Low	Low	High	Extirpated	High
Canada	Ontario	Grey	Jones's Falls				Low	Medium	Low	High	Historical	High
Canada	Ontario	Grey	Wiarton area				Low	Low	Low	High	Historical	High
Canada	Ontario	Grey	Saugeen River				Low	Low	Low	High	Historical	High
Canada	Ontario	Bruce	1-1.5 Miles E Stokes Bay				Low	Low	Low	High	Historical	High
Canada	Ontario	Grey	Hayward Falls, Rocky Saugeen River				Low	Low	Low	High	Historical	High
Canada	Ontario	Grey	5 KM S Singhampton				Low	Low	Low	High	Historical	High
Canada	Ontario	Simcoe	East of Edward Lake				Low	Low	Low	High	Historical	High
Canada	Ontario	Grey	1 Mile E Eugenia				Low	Low	Low	High	Historical	High
Canada	Ontario	Grey	3 Mile E Eugenia				Low	Low	Low	High	Historical	High
Canada	Ontario	Grey	6 - 7 KM NE Hepworth				Low	Low	Low	High	Historical	High
Canada	Ontario	Grey	3.5 KM W Goring				Low	Low	Low	High	Historical	High