Species Status Assessment Report
for the
Relict Trillium
(*Trillium reliquum*)

Version 1.1

August 2023

U.S. Fish and Wildlife Service
Southeast Region
Atlanta, GA

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VERSION UPDATES

The changes from version 1.0 (March 2022) to version 1.1 are minor and do not change the assessment of risk. The following changes were made based on peer and partner reviews:

1. Updated acknowledgements
2. Corrected grammatical errors
3. Corrected formatting
4. Simplified discussion regarding climate change
5. Clarified various components based on peer and partner reviews

EXECUTIVE SUMMARY

Background

Relict trillium (*Trillium reliquum*) is in the Melanthiaceae family and occurs most often in relatively undisturbed rich wooded areas with a mature hardwood overstory canopy in rich ravines and on stream terraces, and soils overlaying calcium-rich bedrock such as amphibolite or limestone. Relict trillium is known to occur in four watersheds (Altamaha, Apalachicola, Choctawhatchee, and Savannah) in Alabama, Georgia, and South Carolina, with most populations occurring in Georgia. The habitats where relict trillium occurs comprise mixed hardwood forests of trees and shrubs that provide shaded to partially shaded conditions. Relict trillium requires shaded conditions and prefers little to no vegetative competition. The primary factors influencing the species' viability in the past, present, and future include habitat destruction and modification from urbanization, agriculture and silviculture, and changes related to climate change. Other factors negatively influencing the trillium include forest structure alteration from storms (e.g., tornadoes), herbivory from white-tailed deer, and impacts from feral hogs. Small population sizes increase risk from these factors. Maintaining intact mixed hardwood forest and habitat protection and management are important conservation strategies for relict trillium viability.

Methodology

The Species Status Assessment (SSA) Report follows three sequential stages. During the first stage, we considered relict trillium's life history and individual, population, and species' needs to maintain viability. In the second stage, we evaluated demographic and habitat factors of extant populations and assessed the current condition of the species through the conservation biology principles of resiliency, representation, and redundancy. The final stage of the SSA Report involved making predictions about future viability while considering the species' responses to anthropogenic and environmental influences that are likely to occur within its range. This process used the best available information to characterize viability as the ability of a species to sustain populations in the wild over time.

We delineated populations of relict trillium using occurrence data obtained from state agency databases (i.e., Alabama, Georgia, and South Carolina Natural Heritage databases) and other partner surveys. We used NatureServe's Habitat-based Plant Element Occurrence Delineation Guidance when delineating populations. The species was divided into six Representative Units (RUs). Representative Units consist of four HUC-6 Watersheds: 1) Altamaha; 2) Apalachicola; 3) Choctawahatchee; and 4) Savannah. Two of those watersheds, Apalachicola and Savannah, are further subdivided into eastern and western units reflecting genetics information. We made qualitative assessments of the current condition (viability) for each population, by evaluating the species' population characteristics (demographic factors) and its physical environment (habitat factors). Demographic factors included population size and evidence of reproduction. Habitat factors included condition of the vegetation (forest structure), and evidence of other habitat factors such as adjacent land use, hydrologic impacts, nonnative invasive plants, white-tailed deer herbivory, and/or feral hog damage.

We further defined how each of these factors might vary in terms of condition (i.e., high, moderate, low, very low). These factors were selected because the supporting data were available across the range of the species and at a resolution suitable for assessing the species at the population level. To assess the species' current condition, we developed resiliency condition scores for each relict trillium population and assessed species' representation and redundancy across its range.

Then, we assessed the species' future condition and potential viability under four future scenarios. We chose to model these scenarios at years 2040 and 2080 because of the average lifespan of the species (at least 40 years), confidence in models and projections of factors influencing the species' viability, and certainty in predictions of the species' response to those factors. We assessed future conditions for the relict trillium under three plausible future scenarios related to two habitat influences from (1) urbanization (SLEUTH model), (2) climate influenced land use change (FORE-SCE model), and other site-specific habitat factors (i.e., adjacent land use, nonnative invasive plants, and/or feral hog damage). The scenarios included: (1) Status Quo - Lower Emissions, (2) Status Quo - Higher Emissions, (3) Increased Impacts - Higher Emissions, and (4) Conservation.

Results

Current Condition

We assessed relict trillium's current condition based on population resiliency and the species' representation and redundancy using 61 delineated populations. Of the 61 populations, 44 were considered current (i.e., extant, naturally occurring populations with reliable data and observed since 2002) and were further assessed for resiliency based on survey data. In our assessment of the current resiliency of these 44 populations, 10 (23 percent) have high, 12 (27 percent) have moderate, 20 (45 percent) have low, and 2 (5 percent) have very low population resiliency. High and moderate resiliency was largely due to high abundance of individuals with most of these also exhibiting good quality habitat structure (overstory, midstory, shrub and groundcover components). All populations had some evidence of non-native invasive plants, feral hogs, deer browsing and/or hydrologic impacts. Extensive evidence of invasive non-native plants and deer browse were the most prevalent habitat threats range-wide and were the primary factors affecting the low to very low resiliency populations.

Of the 44 current populations, 22 currently exhibit low or very low resiliency along with 12 historical populations. Although a trend analysis was not possible with the available data, qualitative and anecdotal information gleaned from state Natural Heritage Program records suggest a decline in both representation and redundancy.

Populations are currently extant with varying levels of resiliency across all six RUs (Table Ex.1). The ten high resiliency populations are almost all located in the center of the range in the Apalachicola East, Altamaha, and Savannah West RUs (in the state of Georgia) and 12 moderate resiliency populations are distributed throughout the range of the species. The western extent (Alabama populations, Choctawhatchee and Apalachicola West RUs) and the eastern extent (South Carolina, Savannah East RU) represent the populations with the highest genetic diversity but have low redundancy compared to the RUs in the central portion of the range. However, those RUs contain two to three high to moderate resiliency populations. Therefore, currently relict trillium has some level of adaptive capacity (representation) and ability to rebound after catastrophic events (redundancy).

Table Ex.1. Population resiliency for the 44 categorized populations by Resiliency Unit. Resiliency Units are ordered from west to east. Numbers in parentheses indicates numbers of those populations on protected lands.

Resiliency Unit	State	Populations with High Resiliency	Populations with Moderate Resiliency	Populations with Low Resiliency	Populations with Very Low Resiliency
Choctawhatchee	AL	0	3	3	0
Apalachicola West	AL	1	1	2(1)	1
Apalachicola East	GA	4(3)	5(2)	12(4)	1(1)
Altamaha	GA	4(1)	1(1)	3(1)	0
Savannah West	GA	1	0	0	0
Savannah East	SC	0	2	0	0
Total		**10(4)**	**12(3)**	**20(6)**	**2(1)**

Future Condition

We predicted the future resiliency of the 44 relict trillium populations at two time steps (2040 and 2080) using four scenarios that take into account a range of impacts from future urbanization, climate-influenced (emissions) land use change, and habitat threats (i.e., non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts). The scenarios were: (1) Status Quo – Lower Emissions, (2) Status Quo – Higher Emissions, (3) Increase Impacts – Higher Emissions, and (4) Conservation.

In the future, impacts to relict trillium population resiliency are predicted to increase and population resiliency generally decreases across scenarios and time steps from Scenarios 1 to 3, with some resiliency conserved in the Conservation scenario (Table Ex.2). Of the assessed populations, 18 (40 percent) of the populations are predicted to be affected by urbanization in one or more scenarios or time steps, with a range of increased percent urbanized acres of 0.2 to 88.8. Fourteen populations (31 percent) were predicted to be negatively affected by land use change through the loss of 0.35 to 100 percent of suitable habitat. Range wide three to five populations are forecasted to be extirpated. Most remaining future populations under all scenarios and time steps are located in the Apalachicola East RU (20 to 22) followed by the Altamaha RU (6 to 7), Choctawhatchee RU (5 to 6), Apalachicola West RU (4), Savannah East

RU (1 to 2) and Savannah West RU (1). Table Ex.2. Future resiliency for the 44 known relict trillium populations in 2040 and 2080 under four future scenarios. Total estimated populations under each Scenario and resiliency category are listed for two time steps in 2040 followed by 2080 estimates, displayed as 2040 Estimate / 2080 Estimate.

Resiliency	**Current**	**Scenario 1 Status Quo – Lower Emissions**	**Scenario 2 Status Quo – Higher Emissions**	**Scenario 3 Increased Impacts – Higher Emissions**	**Scenario 4 Status Quo – Higher Emissions with Conservation**
High Resiliency	10	2 / 0	2 / 1	1 / 1	4 / 2
Moderate Resiliency	12	6 / 9	10 / 6	9 / 4	9 / 6
Low Resiliency	20	22 / 19	15 / 18	15 / 16	14 / 18
Very Low Resiliency	2	11 /14	14 / 17	14 / 18	14 / 16
Extirpated	0	3 / 2	3 / 2	5 / 5	3 / 2
Total High and Moderate Resilience	22	8 / 9	12 / 7	10 / 5	13 / 8

Future representation and redundancy for the species was predicted under these scenarios and time steps by assessing the number of relict trillium populations in the six RUs (watersheds) and assessing the number of resilient and representative populations distributed across the range of the species. In the future scenarios, all RUs continue to be represented; however, redundancy is predicted to decline across all RUs in each scenario and time step due to declines in population resiliency and extirpations. The eastern (South Carolina, Savannah East RU) and western (Alabama, Choctawhatchee and Apalachicola West RUs) extents of the species' range represent the highest genetic diversity but have low to no redundancy of resilient populations in most future scenarios and time steps. The Savannah East and Savannah West RUs have no resilient populations, the Choctawhatchee RU has only two to three resilient populations, and the Apalachicola West RU has one resilient population remaining and there is at least two extirpations in all future scenarios. This reduction in representation and redundancy may increase risk to the species by reducing adaptive capacity (low representation in genetically significant RUs) and increase vulnerability to impacts from catastrophic events (low redundancy).

Conclusion

In conclusion, relict trillium populations are predicted to generally decline in resiliency overtime due to habitat-based impacts from urbanization, land use change, and impacts from habitat threats. The resilient populations (high and moderate resiliency) are predicted to change from an estimated 22 populations to a range of 5 to 12 across scenarios and time steps and are in as many as four RUs and as few as three RUs depending on scenario and time step. The future models predict as many as five of the six RUs will lack redundancy depending on the scenario and time step. Conservation (management of habitat threats on protected lands) may increase the potential to maintain resilient populations in some RUs and across the range. Therefore, based on the scenarios assessed, relict trillium is expected to have some level of adaptive capacity (representation) and ability to rebound after catastrophic events (redundancy).

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CHAPTER 1: INTRODUCTION AND ANALYTICAL FRAMEWORK

1.1 Background and Federal Actions

The Species Status Assessment (SSA) framework (Service 2016, entire) is intended to support an in-depth review of a species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The SSA forms the scientific basis for decisions under the U.S. Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531-1543). It is a living document, to be easily updated as new information becomes available, and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery (Smith et al. 2018, entire).

Trillium reliquum (hereafter, relict trillium) is a long-lived spring ephemeral perennial plant of the Melanthiaceae family and is endemic to Alabama, Georgia, and South Carolina. The natural habitat for relict trillium is relatively undisturbed, moist hardwood forests in rocky clay to alluvial sandy soils with high organic matter content in the upper soil layer. In 1988, this species was listed by the U.S. Fish and Wildlife Service (Service) as "Endangered" under the ESA, (53 FR 10879 (Service 1988)) due to ongoing threats from loss or degradation of habitat due to development, timber harvest, or fire; invasion of non-native species; and inadequacy of existing regulatory mechanisms. Importantly, the SSA does not result in any decisions or actions by the Service. Rather, this SSA provides a review of the available information strictly related to the biological status of relict trillium. Any future decisions by the Service will be made after reviewing this document and all relevant laws, regulations, and policies, and the results of any proposed decisions will be announced in the *Federal Register*, with appropriate opportunities for public input.

1.2 Analytical Framework

For the purpose of this assessment, we define viability as a description of the ability of a species to sustain populations in the wild beyond a biologically meaningful time frame. Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time (Service 2016, p. 9). Using the SSA framework (Figure 1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (together the 3R's) (Wolf et al. 2015, entire). A species with a high degree of resiliency, representation, and redundancy (the 3Rs) is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith et al. 2018, p. 306).

Resiliency is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011, p.

40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

We can best gauge resiliency by evaluating population level characteristics such as: demography (abundance and the components of population growth rate -- survival, reproduction, and migration), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity. Also, for species prone to spatial synchrony (regionally correlated fluctuations among populations), distance between populations and degree of spatial heterogeneity (diversity of habitat types or microclimates) are also important considerations. For relict trillium, we evaluate resiliency by assessing demographic and habitat characteristics for each population.

Representation is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments (referred to as adaptive capacity) is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either (1) moving to new, suitable environments or (2) by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Beever et al. 2016, p. 132; Nicotra et al. 2015, p. 1270). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, p. 290-291; Sgrò et al. 2011, p. 327; Zackay 2007, p. 1).

We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which might include measures of interpopulation genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess (1) natural levels and patterns of gene flow, (2) degree of ecological diversity occupied, and (3) effective population size. In our species status assessments, we assess all three facets to the best of our ability based on available data. For relict trillium, we have limited genetic diversity information. However, populations with the highest genetic diversity are in the eastern and western extremes of the geographic range (Gonzales and Hamrick 2005, p. 313). Further, Gonzales and Hamrick (2005, p. 312) found associations within major watersheds may be an important factor for shaping the genetic structure in relict trillium, especially for populations separated by the Chattahoochee River. Therefore, we summarized the number and resiliency of populations across six Representation Units (watersheds).

Redundancy is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population heath and for which adaptation is unlikely (Mangal and Tier 1993, p. 1083). We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level. For relict trillium, we determined the number and distribution of resilient populations across the species current range to measure redundancy.

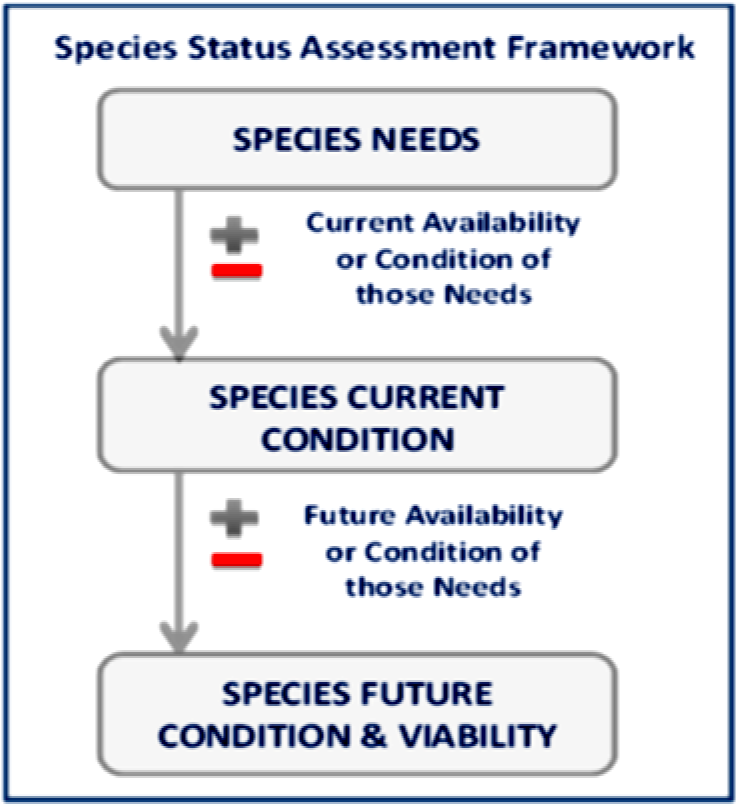

Figure 1. Species status assessment framework

To evaluate the viability of relict trillium, we assessed a range of conditions to allow us to consider the 3R's for this species. This SSA report provides a synthesis of the species' biology and natural history and assesses risks, stressors, and influencing factors in the context of determining the viability of the species. The format for this SSA includes relict trillium biology and resource needs from the individual to species level (Chapter 2), influences on viability (Chapter 3), current condition (Chapter 4), and future condition and viability (Chapter 5).

CHAPTER 2: SPECIES BIOLOGY AND NEEDS

In this chapter, we provide biological information about relict trillium including its taxonomic history, morphological description, historical and current distribution and range, and known life history. We then outline the resource needs of individuals.

2.1 Taxonomy

Trillium, a genus first established by Carl Linnaeus in 1753, is a monophyletic (Farmer and Schilling 2002, p. 687) genus of herbaceous plants in the bunchflower family (Melanthiaceae) (Tamura et al. 2004, p. 117; APG 2016, p. 15). Trilliums were initially placed in the lily family (Liliaceae) but have been alternatively placed in other families throughout the 20th century, primarily in the trillium family (Trilliaceae) (Farmer and Schilling 2002, p. 675; Zomlefer 1996, p. 94-95). The systematics of the family are not resolved (Farmer and Schilling 2002, p. 674).

Approximately fifty (50) species of *Trillium* are recognized globally from temperate areas of North America and eastern Asia (Weakley 2020, p. 201), with over forty (40) of these from North America (Weakley 2020, p. 202-203). The epicenter of diversity in North America is the eastern United States, particularly the southern Appalachian Mountains (Figure 2).

The *Trillium* genus has traditionally been separated into two sub-genera: the pedicellate-flowered taxa (subgenus *Trillium*); and the sessile-flowered taxa (subgenus *Sessilium*) (Freeman 1975, p. 2), the latter formerly (and mis-appropriately) referred to as subgenus *Phyllantherum* (Reveal and Gandhi 2014, p. 1). The sessile-flowered *Trilliums* are considered the more derived of the two, only found in North America (Freeman 1975, p. 2), and are monophyletic (as opposed to pedicellate-flowered taxa which are considered paraphyletic) (Farmer 2002, p. 687). Twenty-five species comprise the subgenus *Sessilium* (Case 2003a, pp. 16-38; Weakley 2020, pp. 202-203): *T. albidum, T. angustipetalum, T. chloropetalum, T. cuneatum, T. decipiens, T. decumbens, T. delicatum, T. discolor, T. foetidissimum, T. gracile, T. kurabayashii, T. lancifolium, T. ludovocoanum, T. luteum, T. maculatum, T. oostingii, T. petiolatum, T. recurvatum, T. reliquum, T. sessile, T. stamineum, T. tennesseense, T. underwoodii, T. viride, and T. viridescens*. Freeman (1975, p. 3) further divided the sessile-flowered species into three groups: 1) *T. recurvatum* group; 2) *T. sessile* group; and 3) *T. maculatum* group. Relict trillium was assigned to the *T. sessile* group characterized by prominently prolonged anther connectives, either introse or extrorse anther dehiscence, sharply angled ovaries, and usually linear stigmas.

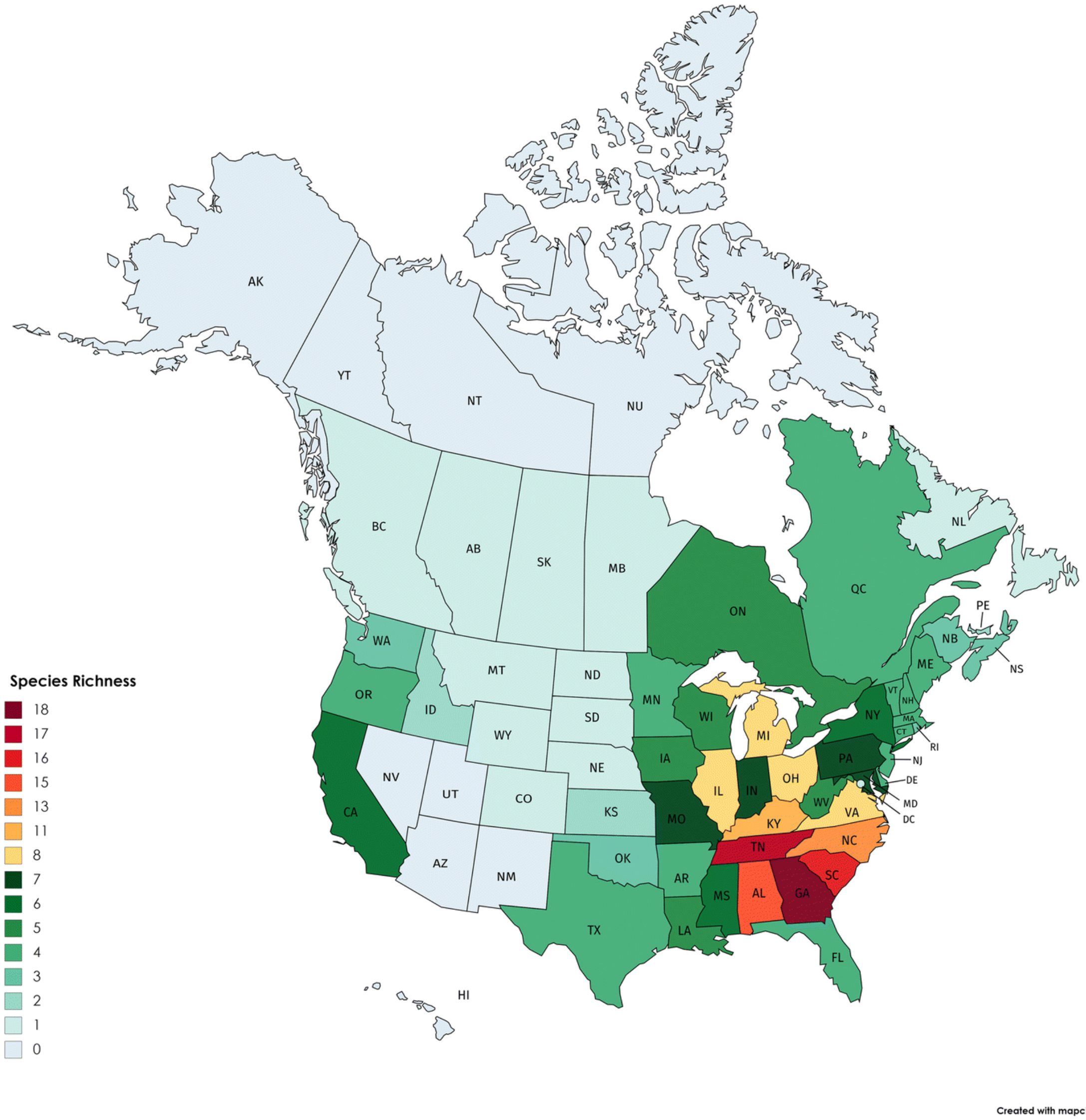

Figure 2. Species richness of *Trillium* spp. recorded in each U.S. state and Canadian province. Borrowed from Chauhan et al. 2019.

Relict trillium (*Trillium reliquum*) was first collected by Alfred Cuthbert (C.V. Starr Virtual Herbarium, n.d.) near Augusta, Georgia in 1902 in rich river soil along the banks of the Savannah River at the "Locks" in either Richmond or Columbia County (Patrick et al. 1995, p. 208). It was identified only to genus at the time. Note: A first collection date of 1901 appearing in Patrick et al. (1995) was in error, as it was actually 1902 (NY Botanical Garden Herbarium 1902, image). A much earlier record of *Trillium* from 1840 by "Doctor Latrobe" in the Carnegie Museum of Natural History was annotated incorrectly as *T. reliquum*. The authority and date of the annotation are unknown. Carnegie Museum of Natural History 1840, image; Isaac 2021, pers. comm.).

John D. Freeman described relict trillium as a new taxon in 1975. Figure 3 shows an adult flowering individual. The Type specimen was collected in 1968 from the same general area as

Cuthbert's first collection above (Freeman 1975, p. 21). Additional discoveries were made on the South Carolina side of the Savannah River (Aiken County) and in extreme southwestern Georgia (Clay and Early counties) (Freeman 1975, p. 21). At the time of description, the plant was known from just a few widely separated population clusters in relatively undisturbed settings, suggesting relictual status from an earlier time of greater abundance, hence the specific epithet "reliquum" (Patrick et al. 1995, p. 208).

Figure 3. Typical adult flowering relict trillium (left) and rare yellow form (right). Credits: Lissa Leege (Georgia Southern University) and Gemma Milly (GA Department of Natural Resources).

The currently accepted taxonomic ranking for relict trillium is described below*.

Kingdom: Plantae
  Subkingdom: Viridiplantae
    Infrakingdom: Streptophyta
      Superdivision: Embryophyta
        Division: Tracheophyta
          Subdivision: Spermatophytina
            Class: Magnoliopsida
              Superorder: Lilianae
                Order: Liliales
                  Family: Melanthiaceae – bunchflowers
                    Genus: *Trillium* L. – trilliums
                      Species: *Trillium reliquum* Freeman – Relict Trillium

*Retrieved 05/20/2021 from the Integrated Taxonomic Information System (ITIS 2021) on-line database, http://www.itis.gov.

2.2 Genetics

A study by Gonzales and Hamrick (2005, p. 311-313) found strong genetic differentiation among the 22 occurrences sampled. In their research, a relationship could not be established between population size and genetic diversity. They did discover a statistically significant trend of decreasing heterozygosity from east to west, particularly when populations west of the Chattahoochee River were excluded from analyses, because relict trillium populations at either margin of the geographic range had the highest proportion of polymorphic loci. The Alabama occurrences in particular had a relatively high number of private alleles.

Gonzales and Hamrick (2005, p. 311-313) concluded that there is no appreciable gene flow among relict trillium populations and that historically there was little genetic interchange between populations. They contend that the rarity and the isolated nature of the populations are characteristic of a species of ancient origin rather than one reflecting recent habitat fragmentation following European colonization, and that this plant could be viewed as a species comprising several ancient and genetically diverse populations. Gonzales and Hamrick (2005) results also suggest that the Alabama and Georgia populations, separated by the Chattahoochee River which is acting as an effective barrier to genetic interchange, may represent different historical lineages both before and after the last glacial maxima. As such, the Alabama and Georgia populations can be viewed as having originated from separate glacial refugia on opposite sides of the Chattahoochee River.

2.3 Species Description

Relict trillium is a perennial herb with a glabrous (hairless) scape (stem) 6-18 centimeters (cm) (2.4-7 inches (in)) in length. The scape is decumbent (prostrate) or semi-decumbent with the bracts (leaves) resting (or nearly so) on the ground or leaf litter but with leaves facing upward (Case 2003a, entire; Chafin 2020, entire). The scape is also frequently described as having a strong "S-curve" shape. This characteristic is lacking or poorly expressed in many cases and is not a reliable diagnostic feature (Bowling 2021a. p. 2). Lack of "S-curve" is especially prevalent in cultivation (Case 2003a, webpage unpaginated; Case 2003b, webpage entire). Trilliums are considered trimerous, meaning plant parts appear in sets or multiples of three. The leaves in mature individuals almost always number three, with seedlings (cotyledon stage) being single-leaved; sexually immature plants are both one and three-leaved (Ohara 1989, p. 5; Rottinik 2016, entire). Four-leaved individuals (tetramerous) are unusually common for a trimerous genus. Five-leaved (pentamerous) and even two-leaved (dimerous) individuals are also reported (Zomleffer 1996, pp. 104-105; Case and Case 1997, p. 21). Leaves are 5 - 12 cm (2 - 4¾ in) long and 6 - 10 cm (2½ - 4 in) wide. They are ovate (egg-shaped – attached at broad end) to elliptic (narrow oval) in shape and arranged in a whorl at the top of the stem. Leaves of older plants are rounded, being nearly as wide as long and overlapping at the base. They are mottled in 5 shades of green with a silvery to light-green streak along the midvein. The flower, at the center of the whorl of leaves, is sessile (has no flower stalk), and it frequently smells fetid and putrid – like rotten meat. Flower scent varies among individual flowers and is high dependent on a surveyor's sense of smell, thus it is also considered an unreliable diagnostic characteristic (Milly 2022, pers. comm.). Sepals are three per flower, spreading to loosely ascending, green to maroon. Petals are 2.5 - 5.5 cm (1 - 2 in) long, three per flower; maroon, green, or rarely yellow (forma *luteum*) (Freeman 1975, p. 21). Stamens are six per flower. Each stamen is composed of dark purple connective tissue flanked by two vertical pollen sacs (anthers) opening to release the yellow pollen. The tip of the anther is distinctly pointed like a beak (Figure 4). The fruit is a fleshy capsule with three locules, about 1 cm (½ in) long, maroon, oval, six-angled. Seeds are ellipsoidal and concaved. Within and around the concavity is a fleshy appendage, rich in oil and fat, known as an elaiosome.

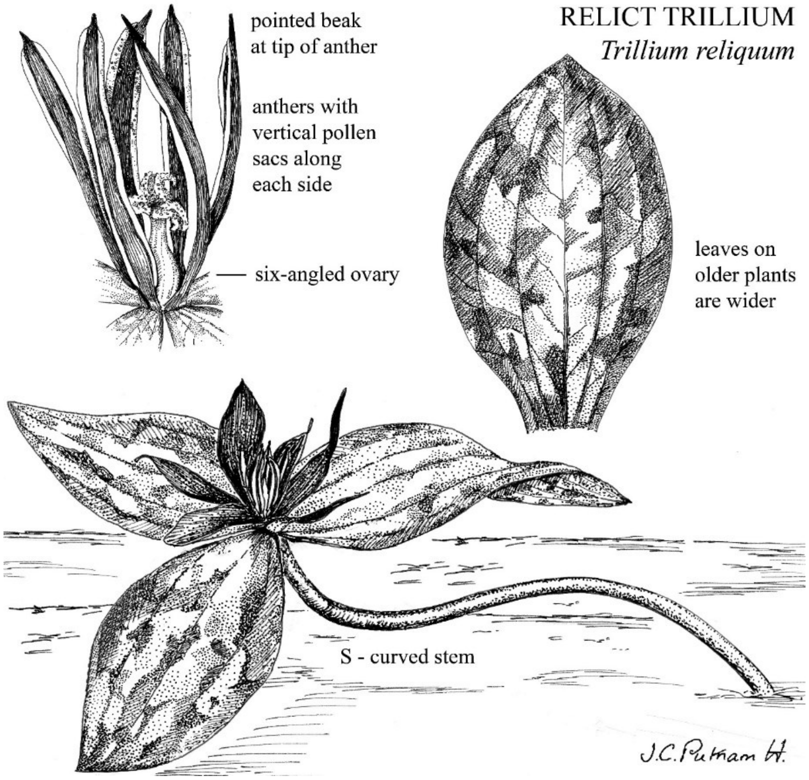

Figure 4. Botanical illustration of relict trillium by Jean C. Putnam (Chafin 2020, entire). Used with permission of State Botanical Garden of Georgia.

Freeman's (1975, p. 21) formal description includes references to other *Trillium* species: decumbent trillium (*T. decumbens*); Underwood's trillium (*T. underwoodii*); and Chattahoochee trillium (*T. decipiens*). Collectively these species, along with the newly described Ocmulgee trillium (*T. delicatum*) and an undescribed taxon with the provisional name of the little-known trillium (*Trillium* "*reconditum*" ined.), constitute a morphologically similar group known as "silverbacks" (Bowling 2021a, unpaginated). Members of this group have mottled leaves (bracts) with three to five shades of green or silvergreen, and/or a central light green or silver stripe. Silverback taxa have overlapping ranges (central and southern Alabama, the panhandle of Florida, and southwestern/west central Georgia) and are frequently the source of taxonomic confusion and misidentification in the field (Bowling 2021b, pers. comm.; Bowling et al. 2021, pers. comm.).

Relict trillium is one of three silverback trilliums, along with decumbent trillium and Ocmulgee trillium, which have very short stems, holding their leaves near the ground, appearing essentially prostrate (Weakley 2020, p. 202). Relict trillium is distinguished from Ocmulgee trillium by having a glabrous decumbent or semi-decumbent scape with an S-curve, whereas Ocmulgee trillium has a straight scape that is densely puberulent (covered with fine downy hairs) on angled edges (Weakley 2020, p. 202). Decumbent trillium and relict trillium both have S-curve shaped scapes, however the decumbent trillium scape is densely puberulent below the bracts and on main veins beneath the bract (WFO 2022, entire; Chaffin 2020, entire). Additionally, the anthers are in an extrorse (facing outward) position in decumbent trillium, while they are introrse (inward facing) in relict trillium (Weakley 2020, p. 202). Decumbent trillium's leaves are also mottled with just one shade of green and silver, whereas relict trillium's mottling includes four shades of green and a silver mid-vein stripe. Recent extensive field observations by Milly (2022, pers. comm.) suggest that scape shape and orientation are not reliable diagnostic characteristics.

2.4 Habitat

Relict trillium is found in rich mesophytic woods (Figure 5) and mature hardwood forests on bluffs, in ravines and ravine slopes, as well as along older stream terraces and small stream floodplains that experience limited over bank events due to vertical distance above the stream from deep stream cutting (Freeman 1975, p. 21; Case and Case 1997 p. 227; Edwards et al. 2013, p. 273). These sites are generally moist, but well-drained, and have some association with limestone or mafic (amphibolite and gabbro) geology. In the Coastal Plain, these sites often contain boulders or are developed upon soft limestone ledges (Patrick et al. 1995 p. 208; Chafin 2020, entire), while in the Piedmont they are associated with deep loamy soils or found in shallower soils located in low/concave-shaped slopes that collect nutrients in otherwise nutrient-average settings (Patrick et al. 1995, p. 208; Edwards et al. 2013, p. 273).

Figure 5. Hundreds of relict trillium plants in classic mesophytic woods. Note flowering and non-flowering adults, as well as one and three-leaved juveniles. Credit: Tom Govus.

Climatological data collected from 1980 to 2020 by the National Climatic Data Center of the United States (National Oceanic and Atmospheric Administration [NOAA] 2021, entire) were compiled for counties representing the geographic extent of the relict trillium range in Alabama, Georgia, and South Carolina. These county level data indicate a general trend of average annual temperatures and precipitation both declining along a west/southwest to east/northeast gradient, running from southeastern/central-eastern counties in Alabama (i.e., Bullock, Henry, and Lee) and counties in southwestern Georgia (i.e., Clay and Early) towards counties near Augusta, GA (i.e., Columbia) and North Augusta, SC (i.e., Aiken and Edgefield. During the 1980 to 2020 period, average annual temperatures ranged from 16.9 to 19.2 degrees Celsius (°C) (62.4 to 66.5 degrees Fahrenheit (°F)). Summers are hot with average monthly maximum temperatures between 28.8 to 36.2 °C (83.0 to 97.1 °F)) during June thru August, the hottest part of the year. Winters are mild with occasional low temperatures below freezing; the average monthly minimum winter temperature is between -2.6 and 9.7 °C (27.3 and 49.5 °F) from December to February, the coldest part of the year. The average annual precipitation range is 114.8 to 135.9 cm (45.2 to 53.5 in) with minimums and maximums ranging between 80.8 and 200.7 cm (31.8 and 79 in).

Review of species locations and associated elevations from U.S. Geological Survey (USGS) topographic maps shows the species generally occurs at low elevations from 61 to 152 meters (m) (200-500 feet (ft)) above sea level. The lowest elevation of approximately 23 m (75 ft) is in Henry County, Alabama, near the Chattahoochee River; the highest elevation of approximately 229 m (750 ft) is in Harris County, Georgia, on the north slope of the Pine Mountain Ridge.

Relict trillium is a spring ephemeral, meaning it emerges in late winter/early spring, prior to many other competing plant species to take advantage of the bright light, but cool winter/spring temperatures, provided by a leafless deciduous canopy. It is adapted to shaded to partly shaded conditions (low to moderate light intensities) during the rest of the growing season, almost always in habitats with a mature forest canopy. The midstory and shrub layer levels are relatively sparse and open in the most robust sites. We hypothesize that these relatively open midstory areas are preferred due to reductions in competition for resources, especially light. However, shade tolerance as it relates to complex community level and ecosystem dynamics, abiotic stress, and resource tradeoffs, polytolerances (e.g., tolerance to multiple stressors), plant-plant, and plant-animal interactions is poorly understood, making evaluation of an individual species' shade tolerance challenging (Vallardes et al. 2016, pp. 237-238, 246).

The habitat also contains a low evergreen component overall. This is typical forest structure and composition of many spring ephemeral habitats. This structure supports the life history strategy of a spring ephemeral which needs to emerge from dormancy, bloom quickly, and complete its above ground life cycle during the low competition, high light period before the canopy closes with the emergence of leaves from understory and overstory deciduous trees and shrubs (Kim et al. 2015, pp. 164-165).

Vegetation present in relict trillium habitats throughout the range is consistent with that found broadly in Piedmont mesic forests and Coastal Plain mesic slope forests in Edwards et al. (2013 pp. 273-276 and 405-409). A vegetation profile (below) was developed to describe areas where relict trillium commonly occurs using information provided by Alabama Natural Heritage Program (ANHP) at Auburn University, the Georgia Natural Heritage Program (GNHP) at the Georgia Department of Natural Resources, and the South Carolina Heritage Trust Program (SCHTP) at the South Carolina Department of Natural Resources (collectively referred to State Natural Heritage Programs), as well as the Waddell (2006, entire) thesis. Typical habitat associated with relict trillium occurrences includes:

> Dominant and less frequent **canopy tree species** were: chalk maple (*Acer leucoderme*), red maple (*A. rubrum*), Carolina shagbark hickory (*Carya carolinae-septentrionalis*), red hickory (*C. ovalis*), other hickories (*Carya* spp.), sugarberry (*Celtis smallii*), American beech (*Fagus grandiflora),* black walnut (*Juglans nigra*), sweetgum (*Liquidambar syraciflua*), tuliptree (*Liriodendron tulipifera*), black gum (*Nyssa sylvatica*), spruce pine (*Pinus glabra*), loblolly pine (*P. taeda*), sycamore (*Platanus occidentalis*), white oak (*Quercus alba*), southern red oak (*Q. falcata*), Darlington oak (*Q. hemisphaerica*), swamp chestnut oak (*Q. michauxii*), water oak (*Q. nigra*), black oak (Q. *velutina*), Shumard oak (*Q. shumardii*), American basswood (*Tilia americana*), winged elm (*Ulmus alata*), and other elms (*Ulmus* spp.).
>
> Dominant and less frequent **midstory trees** included: southern sugar maple (*Acer floridanum*) hornbeam (*Carpinus caroliniana*), redbud (*Cercis canadensis*), flowering dogwood (*Cornus florida*), little silverbell (*Halesia carolina*), American holly (*Ilex opaca*), red cedar (*Juniperus virginiana*), southern magnolia (*Magnolia grandiflora*), red

mulberry (*Morus rubra*), muscadine (*Muscadina rotundifolia*), hophornbeam (*Ostrya virginiana*), and black cherry (*Prunus serotina*).

Dominant and less frequent **shrubs** consisted of: pawpaw (*Asimina* sp.), bottlebrush Buckeye (*Aesculus parviflorum*), red buckeye (*A. pavia*), painted buckeye (*A. sylvatica*), giant cane (*Arundinaria gigantea*), switch cane (*A. tecta*), sweetshrub (*Calycanthus floridus*), hawthorn (*Crataegus* spp.), oakleaf hydrangea (*Hydrangea quercifolia*), mountain laurel (*Kalmia latifolia*), needle palm (*Rhapidophyllum histrix*), blue palm (*Sabal minor*), palmetto (*Serenoa repens*), bumelia (*Sideroxylon* spp.), Small's greenbriar (*Smilax smallii*), other greenbriars (*Smilax* spp.), native azalea (*Rhododendron* spp.).

Dominant and less frequent **herbs and graminoids** found were: green dragon (*Arisaema dracontium*), common jack-in-the-pulpit (*A. triphyllum*), five-leaved jack (*A. quinatum*), pale indian plantain (*Arnoglossum atriplicifolium*), wild ginger (*Asarum arifolium*), ebony spleenwort (*Asplenium platyneuron*), cut-leaved toothwort (*Cardamine concatenata*), thicket sedge (*Carex abscondita*), Cherokee sedge(*C. cherokeensis*), Florida sedge, (*C. floridana*), limestone forest sedge (*C. superata*), other sedges (*Carex spp.*), slender woodoats (*Chasmanthium laxum*), Pipsissewa (*Chimaphila maculata*), Spring beauty (*Claytonia virginica*), Fumewort (*Corydalis flavula*), southern wild comfrey (*Cynoglossum virginianum*), whorled horsebalm (*Collinsonia verticillata*), Carolina larkspur (*Delphinium carolinianum*), round-leaved trailing tick-trefoil (*Desmodium rotundifolium*), witchgrasses (*Dichanthelium* spp.), dimpled trout lily (*Erythronium umbilicatum*), Carolina buckthorn (*Frangula caroliniana*), bedstraw (*Galium aparine*), wild geranium (*Geranium maculatum*), downy rattlesnake-orchid (*Goodyera pubescens*), heartleaf (*Hexastylis* spp.), eastern green violet (*Hybanthus concolor*), Virginia saxifrage (*Micranthes virginiensis*), patridgeberry (*Mitchella repens*), Smallflower baby blue eyes (*Nemophila aphylla*), Virginia pennywort (*Obolaria virginica*), adder's tongue (*Ophioglossum* spp.), violet woodsorrel (*Oxalis violacea*), American ginseng (*Panax quinquefolius*), Virginia creeper *(Parthenocissus quinquefolia*), broad beech fern (*Phegopteris hexagonoptera*), phlox (*Phlox* spp.), blackseed needle grass (*Piptochaetium avenaceum*), mayapple (*Podophyllum peltatum*), smooth solomon's seal (*Polygonatum biflorum*), Christmas fern (*Polystichum acrostichoides*), shooting star (*Primula maedia*), bloodroot (*Sanguinaria canadensis*), black snakeroot (*Sanicula* spp.), nutrushes (*Scleria* spp.),chickweed (*Stellaria media*), rue-anemone (*Thalictrum thalictroides*), cranefly orchid (*Tipularia discolor*), poison ivy (*Toxicodendron radicans*), Catesby's trillium (*Trillium catesbyi*), sweet betsy (*T. cuneatum*), Ocmulgee trillium (*T. delicatum*), mottled trillium (*T. maculatum*), recondite trillium (*T.* "*reconditum*"), southern nodding trillium (*T. rugelii*), bellwort (*Uvularia* sp.), halberd-leaf violet (*Viola hastata*), other violets (*Viola* spp.), and atamasco lily (*Zephyranthes atamasco*).

Non-native invasive plant species include: thorny olive (*Eleagnus pungens*), glossy privet (*Ligustrum lucidum*), Chinese privet (*L. sinense*), Japanese honeysuckle (*Lonicera japonica*), sacred bamboo (*Nandina domestica*), Tiawanese photinia (*Photinia *serratifolia*), kudzu (*Pueraria lobata*), greater periwinkle (*Vinca major*), and periwinkle (*V. minor*).

2.5 Range and Distribution

The known historical and current range of relict trillium is a narrow band of counties running from southeastern Alabama across Georgia to the extreme southwestern edge of central South Carolina (Figure 6). The southwestern end of the range begins southeast of Montgomery, Alabama and angles to the northeast, cutting across the Chattahoochee River into Georgia along the Fall Line, which is the geologic boundary marking the prehistoric shoreline of the Atlantic Ocean as well as the division between the Piedmont and Coastal Plain regions (Edwards et al. 2013, pp. 347-349). The species was originally known from just a few counties in southwestern Georgia (Clay, Early, and Lee), and two counties near Augusta, Georgia, (Columbia and Richmond) and in the adjacent county of Aiken, South Carolina. During the late 1970s, 1980s, and 1990s, the known range was expanded to include Bullock, Henry, and Lee counties, Alabama, as well as additional counties in the Fall Line area of Georgia.

Today rangewide, there are 102 occurrences across 24 counties in the three states of Alabama (13 occurrences, 3 counties), Georgia (54 occurrences, 19 counties) and South Carolina (36 occurrences, 2 counties) according to data obtained from the State Natural Heritage Programs. For this report we use Element Occurrences (EOs) in Georgia and Alabama and Object Identification Numbers (Object IDs) in South Carolina to define occurrences across the range (Appendix A).

The 102 occurrences of relict trillium are distributed across seven Level IV ecoregions (Figure 6) according to Griffith et al. (2001, entire). Those Level IV ecoregions include:

- Southern Outer Piedmont: 61 occurrences
- Sand Hills: 14 occurrences
- Coastal Plain Red Uplands: 7 occurrences
- Southern Hilly Gulf Coastal Plain: 7 occurrences
- Southeastern Floodplains and Terraces: 6 occurrences
- Dougherty Plain: 5 occurrences
- Pine Mountain Ridges: 1 occurrence

These are within the larger scale (Level III) ecoregions the Piedmont and Southeastern Plains. Griffith et al. 2001, entire). Most occurrences (53 percent, 55 of 102 occurrences) are located within 8 kilometers (km) (≈ 5 miles (mi)) on either side of the east/west trending Fall Line; at 16 km (≈ 10 mi) it is over 60 percent of the occurrences (63 of 102).

The geomorphologies and edaphic character of the Southern Outer Piedmont and the Sand Hills are markedly different, with the former characterized by schist, gneiss, and granite rock present in the substrata, or as exposed rock and boulders weathering to acidic soils, and the latter being a narrow belt of yellow, red, and white sandy hills comprising weathered upland sediments.

However, both ecoregions are known to have mafic (amphibolite and gabbro) and limestone inclusions, and bedrock both close to the surface and exposed. The interdigitation of the two ecoregions combining the erosional cutting at the lower limits of the Southern Outer Piedmont and the presence of easily erodible sands in the Sand Hills has created a mosaic of rich ravines and floodplain terraces (Edwards et al. 2013, pp. 259 and 349; Chafin 2020, entire).

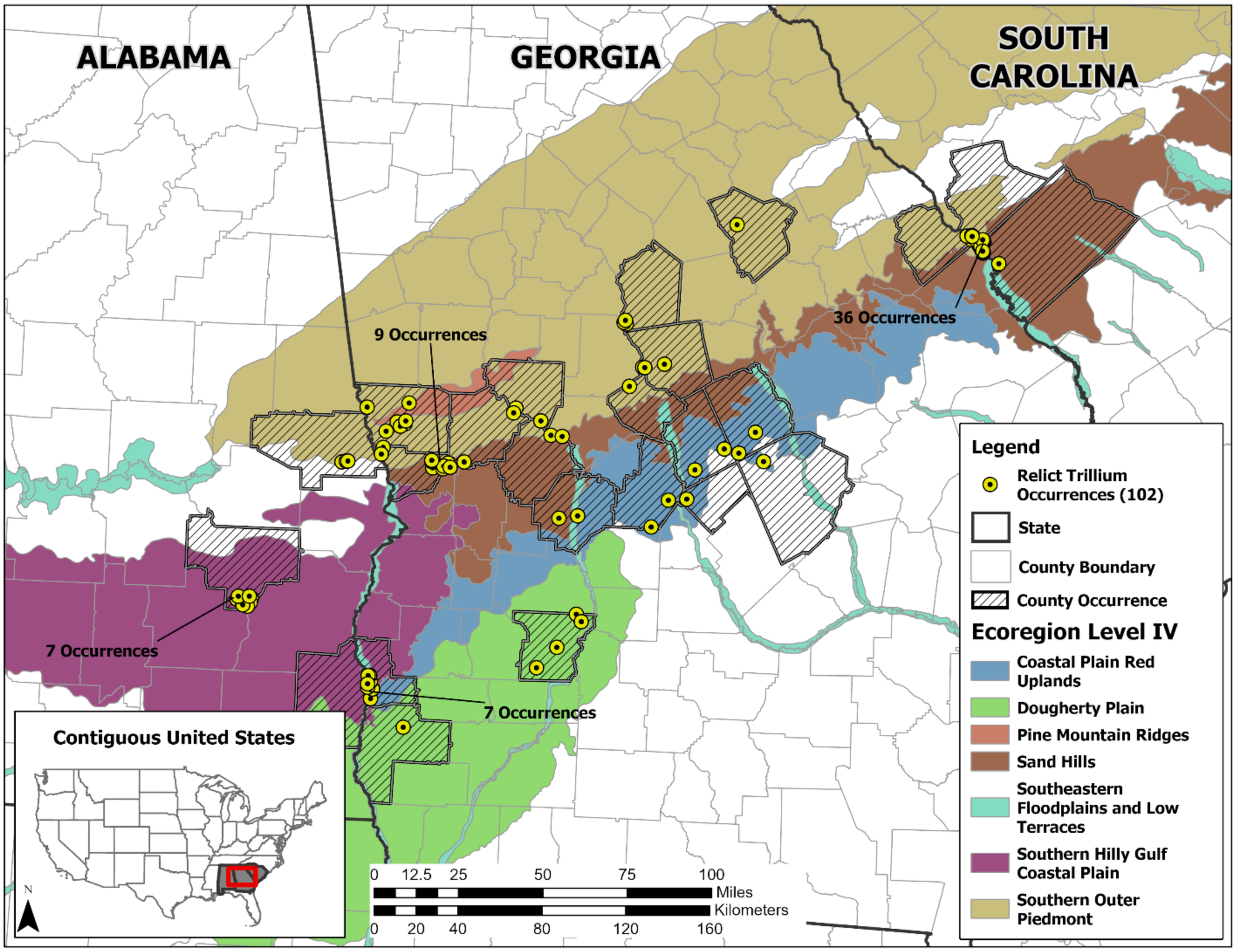

Figure 6. Level four ecoregions within Alabama, Georgia, and South Carolina with the general locations of relict trillium element occurrences.

Relict trillium occurs across four watersheds, two draining to the Atlantic (Savannah and Altamaha) and two draining to the Gulf of Mexico (Apalachicola and Choctawhatchee) (Figure 7). These four watersheds are identified as HUC 6 watersheds (6-digit hydrological [accounting] unit code) (USGS 2020, entire). The 102 relict trillium occurrences include:

- Apalachicola: 42 occurrences
- Savannah: 38 occurrences
- Altamaha: 16 occurrences
- Choctawhatchee: 7 occurrences.

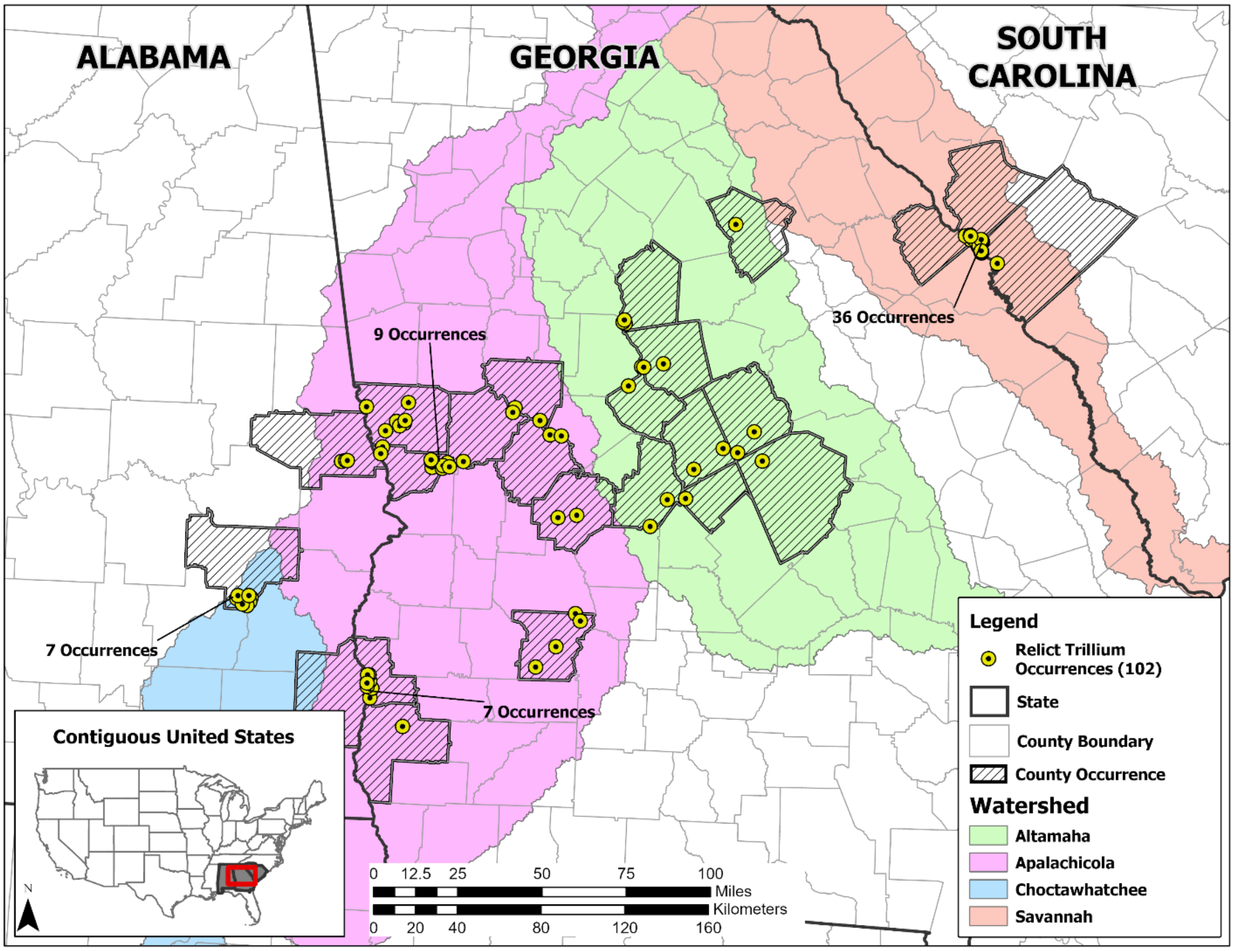

Figure 7. Watersheds (HUC 6) within Alabama, Georgia, and South Carolina with the general locations of relict trillium element occurrences.

2.6 Life History and Individual Resource Needs

Relict trillium is characterized as an herbaceous perennial. Herbaceous plants possess a soft flexible stem, are non-woody, and have no persistent above ground living tissue. The relict trillium is a spring ephemeral, which emerges early (February in Georgia), has a condensed growing season that takes advantage of low competition and bright light conditions in deciduous forests before leaf-out and canopy closure, and then fades quickly in full shade and summer heat (June/July in the Southeastern United States).

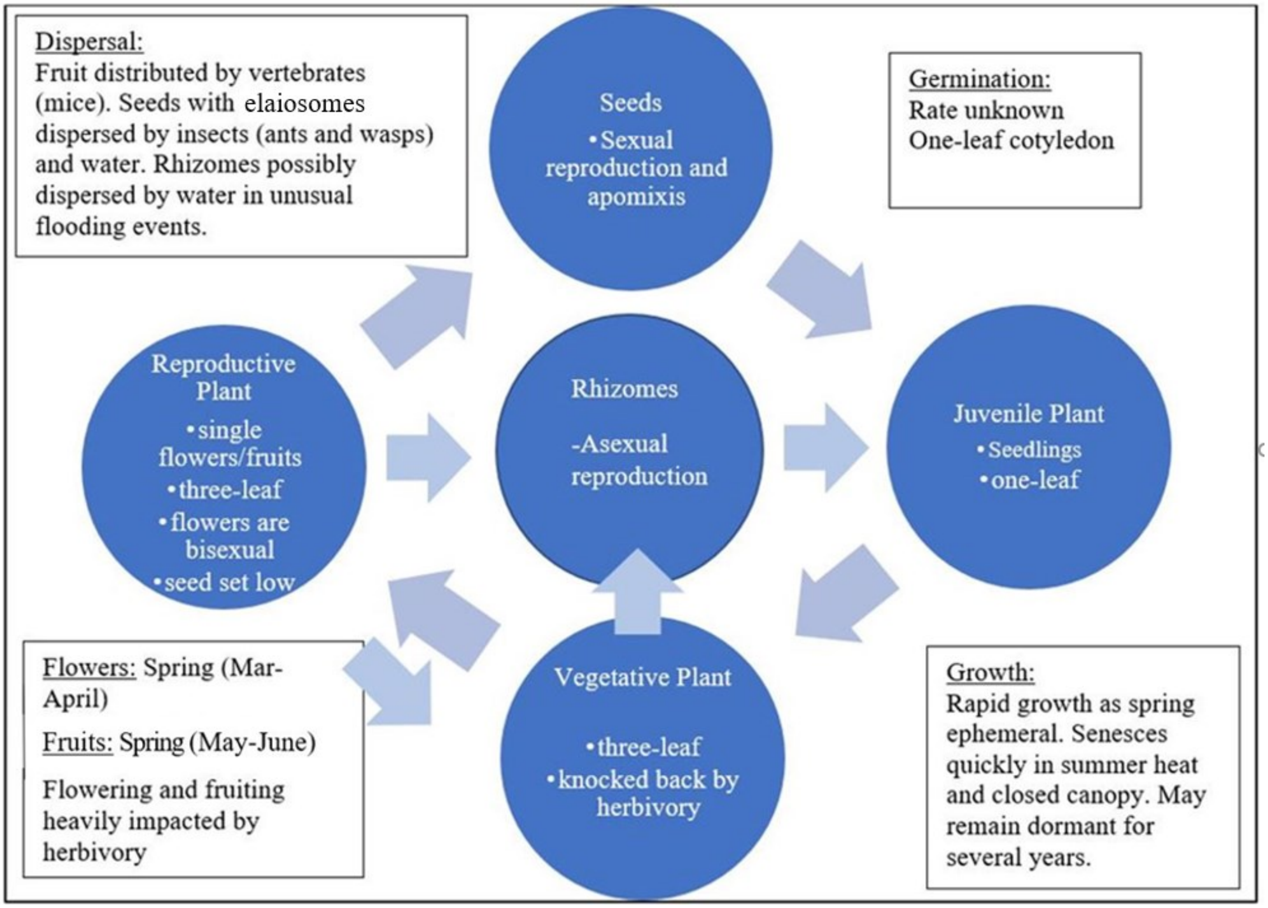

Figure 8. Relict trillium life cycle with life history traits

Relict trillium exhibits a life cycle analogous to other *Trillium* species with individuals exhibiting four distinct morphological stages: (1) seedling; (2) one-leaf juvenile; (3) three-leaf non-reproductive vegetative plant; and (4) three-leaf reproductive plant (Heckel and Leege 2007, p. 52) (Figure 8). However, seeds produced in the current year germinate in spring the following year and produce a single cotyledon. This is different from most North American trillium which have a two-year (double dormancy) germination period. (Case and Case 1997, p. 28, Heckel and Leege 2007, p. 52). Surviving seedlings from year-1 emerge as juveniles the following year with one true leaf. Juveniles from year-2 emerge and may either remain in a juvenile condition, develop into non-reproductive three-leaf plants, or mature into reproductive three-leaf plants. (Heckel and Leege 2007, p. 53). Maturation in experimental horticultural beds takes 5-7 years on average for most Trillium species and it is assumed to be relict trillium shares a similar maturation period. Maturation in nature could take longer (10 years or more) (Ohara 1989, pp. 4-8, Case and Case 1997, p. 30). Some *Trillium* species remain in the same stage for several years before transitioning to the next stage. It is possible for individuals to revert to an earlier stage if damaged or stressed, as well as remain below ground in a dormant state for a year or more (Heckel and Leege 2007, p. 53).

Mature relict trillium are very long-lived, perhaps hundreds of years, with one end of their rhizome continuing to grow and develop shoots as the other end withers and rots (Chafin 2020, entire). Their exceptionally long lifespan and likely advanced age at reproduction, as well as the inability to "age" them accurately using annual rhizome growth rings, makes determination of their exact age and/or the development of precise life-history tables very difficult (Kawano et al. 1992, p. 21; Broyles et al. 2013, p. 1158-1160).

Heckle and Leege (2007, p. 55-57) found that relict trillium reproduces primarily sexually by seed but is also capable of asexual reproduction through both vegetative offshoots and apomixis (the asexual formation of a seed from the maternal tissues of the ovule, thus bypassing meiosis and fertilization). They also demonstrated that relict trillium was capable of self-fertilization (autogamy). Gonzales and Hamrick (2005, p. 306) and Waddell (2006, p. 28), maintain that relict trillium populations are inherently structurally self-incompatible, although they may possess a flawed or "leaky self-incompatible system" that could allow for relatively infrequent self-fertilization events. Vegetative reproduction via offshoots is a limited and slow process as Heckle and Leege (2007, p. 53) observed less than 4 percent vegetative plants in their study. Ohara and Kawano (1986, pp. 4-9) consider relict trillium to have a Type B life cycle and reproductive system relying principally on sexual reproduction, but occasionally forms vegetative offshoots on larger plants. The multi-pronged reproductive strategy for relict trillium (outcrossing, autogamy, and apomixis) provides flexibility (Heckel and Leege 2007, p. 57).

Relict trillium exhibits below average fruit set (41 percent overall) compared to other *Trillium* species; but average seed set (37 percent of ovules developing into seeds) compared with other *Trillium* species (Heckle and Leege 2007, p. 56). One study documented a variable number of ovules per fruit, reaching a maximum of 76, and resulted in 6-49 seeds (per fruit) (Waddell 2006, p. 24). Sessile *Trillium* species, including relict trillium, are characterized by smaller biomass, lower reproductive output, higher allocations towards reproduction, and larger seeds than pedicellate *Trillium* species (Ohara 1989, p. 19). Trilliums, in general, have shown around 20 percent germination success under horticultural conditions (Case and Case 1997, p. 30). The specific germination success rate for relict trillium is unknown.

Freeman (1975, p. 21) described the dark red or purple flowers of relict trillium as having a fetid or putrid smell. Flowers of this color with a rotten or carrion-like scents tend to attract flies and beetles exhibiting a carrion-fly pollination syndrome, known as sapromyophily. This was confirmed by Waddell (2006, p. 28) whose floral visitation observation and experiments identified three families of flies (Dipterans) landing on or swarming above relict trillium flowers: blowflies (Calliphoridae), long-legged flies (Dolichopodidae), and phorid flies (Phoridae). While phorid flies were not observed landing on the flowers themselves, they did constitute the most numerous fly family captured in flowers. Beetles were also a dominant group detected. Tiny scarab beetles (Scarabaeidae) were the most common, with tumbling flower beetles (Mordellidae), sap beetles (Nitidulidae), and shining flower beetles (Phalacridae) were also well represented (Waddell 2006, pp. 28-30).

Waddell's (2006, pp. 32-33) observations and experiments with trillium fruits, seeds and elaiosomes identified several species of ants as the principal group of seed/fruit visitors and, therefore, likely seed dispersers. Small ant species, such as the acrobat ant (*Crematogaster ashmeadi*) and *Paratrchina* (*Paratrechina faisonensis*), as well as larger ant species such as the myrmicine ant (*Aphaenogaster* spp.), night ant (*Camponotus chromaiodes*), and fungus-growing ant (*Trachymyrmex septentrionalis*) (Formicidae) were observed removing fruits and seeds from plants. Ants typically discard the seed and consume the elaiosomes with smaller ant species tending to disperse and discard seeds nearer the parent plant and larger ant species dispersing seeds greater distances (Ohara 1989, p. 5, Waddell 2006, pp. 31-32). Ground beetles foraging at night may transport discarded seeds further than ants (Ohara 1989, p. 5). Vespicochory, seed disperspal by wasps, has been documented in relict trillium by the eastern yellowjacket (*Vespula maculifrons*) (Waddell 2006, p. 33).

2.7 Population and Species Level Needs

For resilient populations to persist, the needs of individuals (suitable habitat and pollinators) must be met at a broader scale, both spatially and temporally. Populations of relict trillium are healthiest in relatively undisturbed rich wooded areas (Figure 9) underlain by calcium-rich bedrock such as amphibolite or limestone with little to no presence of invasive species (Chafin 2020, entire). Habitat area must be large enough to support sufficient relict trillium individuals for cross-pollination that will maintain both healthy population sizes and genetic variation within populations. Population sizes also must be large enough to withstand stochastic environmental, demographic, and anthropogenic events or changes. Because relict trillium is immobile, occupies a narrow range, and resilience of the seed bank is uncertain, populations are likely highly vulnerable to high-intensity, long-lasting, or repeated disturbances. In addition, populations with small number of individuals are vulnerable to local extinctions from unfavorable habitat conditions.

Figure 9. Example of a rich wooded area typical of high-quality habitat for relict trillium. Credit: U.S. Fish and Wildlife Service.

CHAPTER 3: FACTORS INFLUENCING VIABILITY

The following discussion provides a summary of the factors that we believe are substantially affecting or likely to be substantially affecting the current and future condition of relict trillium throughout some or all of its range. These factors include habitat destruction and modification from a variety of sources, disease and predation, climate change, and conservation efforts (Figure 10). Over-collection and poaching were influences considered but were not elaborated on in the following chapter because they are not believed to be substantial threats to relict trillium at this time.

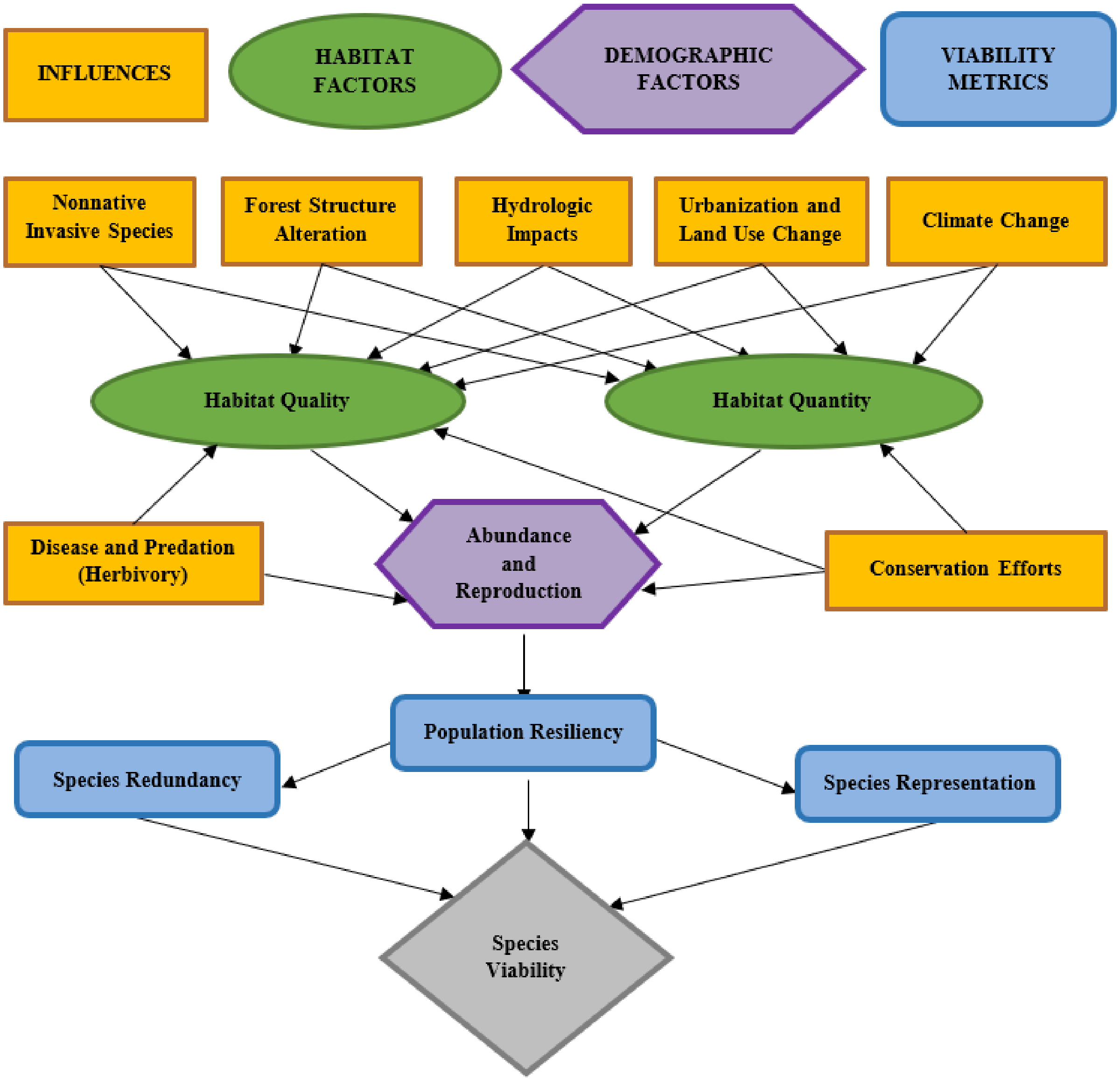

Figure 10. Simplified influence diagram illustrating how various impacts (orange boxes) influence habitat (green ovals) and demographic factors (purple hexagon) that in turn influence the resilience of populations (blue box) and viability of the species (gray diamond).

3.1 Habitat Destruction and Modification

3.1.1 Urbanization, Land Use Change and Hydrological Impacts

Relict trillium is found in habitat that is often well-suited for urbanization, infrastructure construction, and resource extraction activities such as timber harvest. Historically, suitable habitat for this species has been destroyed by residential and commercial development, timber harvest, road construction, and agricultural land conversion (Waddell 2006, p. 9; Heckel and Leege 2007, p. 49). One or more of these activities pose ongoing current threats to all known occurrences of relict trillium as either direct effects, or as the persistent threat of invasive species spreading into disturbed areas. Additionally, natural disturbance events (e.g., tornados) and early forest succession could negatively impact habitat quality or extirpate relict trillium sites.

Through residential and commercial development, urbanization can negatively influence habitat quality and quantity for relict trillium. In addition to direct habitat loss in areas that are not protected, urbanization can result in altered local hydrology from stormwater discharges to streams resulting in reduced or removed floodplain habitat, reduced pollinator movements, and increased invasive species occurrences. For example, riparian and slope habitat at multiple relict trillium element occurrences along small streams and tributaries in Aiken County, South Carolina, were negatively impacted by residential, commercial, and recreational (urban park) development upstream and adjacent to the occurrences. These areas of impact are associated with the urban/suburban interface of natural habitat from the City of North Augusta, Subsequent discharge of stormwater to the streams and overland flow resulted in increased flooding, scouring, erosion, and the degradation of habitat within the floodplain with a corresponding loss of individual plants at some occurrences and likely extirpation of other occurrences altogether (Bradley 2023; Canady 2023). Populations of both native and non-native invasive species, such as deer and feral hogs, may increase along with increasing urban areas due to the lack of predators and abundance of available food sources.

Further indirect impacts from urbanization include fragmentation and loss of connectivity between populations and increased ancillary activities related to residential and commercial development such as construction and maintenance of linear infrastructure (e.g., roads and utility lines). These indirect impacts result in reduced gene flow between populations and the ability to recover from stochastic disturbance events. Runoff from road rights-of-way often result in soil erosion and changes in water runoff patterns that can alter soil and moisture conditions, making habitat unsuitable. Detrimental land uses occurring adjacent to relict trillium populations may alter the natural hydrology of the site and/or influence the vegetation structure and composition.

3.1.2 Forest Structure Alteration

Habitat impacts that open the canopy, destroy soil profiles, and disrupt hydrology (Figure 11) fragment populations and increase edge habitat. These impacts promote the introduction of non-native species (Honu and Gibson 2006, entire). Habitat edges function as sources of propagules for disturbed habitats and represent complex environmental gradients with changes in light availability, temperature, humidity, wind speed, and soil moisture, with plant species responding directly to environmental changes (Meiners et al. 1999, entire). Edge effects, including any canopy break due to timber harvest, fields, or maintained rights-of-way, may penetrate as far as 175 m (574 ft), resulting in changes in community composition (Fraver 1994, p. 830; Meiners et al. 1999, p. 266; Gehlhausen et al. 2000, p.32; Honu and Gibson 2006, p. 264).

Figure 11. Relict trillium habitat modification in Muscogee County, Georgia. Credit: U.S. Fish and Wildlife Service.

Prescribed Fire (burning) is a valuable tool for managing the landscape; however, fire management can adversely impact trillium populations. Trillium occurs in rich, relatively undisturbed mesophytic woods and mature hardwood forests on bluffs, in ravines and ravine slopes, as well as along older stream terraces and small stream floodplains that are not considered fire prone. Most prescribed fire management is conducted in the winter and early spring when fire behavior is more predictable. The trillium rhizome sends up its shoot in late January or early February, it works through the duff layer, and emerges in mid to late February. Furthermore, seeds germinate in the duff layer. The rhizome spends several years growing down through the duff layer until it reaches mineral soil. If a fire burns over a trillium population and consumes the duff layer, then trillium will not flower that year and could destroy several years of recruitment. Frequent fires could eliminate recruitment altogether.

Fire, whether wildfire or prescribed burning, was recognized in the recovery plan as a threat to relict trillium (Service 1991, p. 8). However, as described above, the timing of fire is generally only considered a threat if it occurs during the early spring when relict trillium shoots are present. Trillium populations at Fort Benning and on the Oconee National Forest are in close proximity to populations of red-cockaded woodpeckers (*Leuconotopicus borealis*) where fire is a necessary management tool. One population on Fort Benning was burned in a wildfire during the spring of 2003, destroying the vegetative parts above ground. Annual monitoring has shown an almost complete recovery by the spring of 2006 indicating that relict trillium populations may recover from infrequent fires when given enough time between fires to rebuild energy stores and for habitat to recover (Service 2015, pp.19-20).

3.2 Invasive Species

A non-native invasive species is any organism that is not native to an ecosystem that causes harm. Non-native invasive plant species can outcompete native vegetation, sometimes forming monotypic stands, and limit the available resources (nutrients, water, and sunlight) necessary for relict trillium to become established, juveniles to mature, and for individual plants to reproduce. Non-native invasive plants have been documented from 75 (95 percent) of relict trillium sites and have a substantial or extensive presence at 50 (63 percent) of the sites. For example, encroachment from Japanese honeysuckle and kudzu is documented as representing a significant threat to this rare species (Service 1991, p. 8; Waddell 2006, p. 9; Heckel and Leege 2007, p. 49). In Georgia, thorny olive (*Elaeagnus pungens*) and Japanese stiltgrass (*Microstegium vimineum*) are significant threats (GNHIP 2021, entire). Chinese privet (*Ligustrum sinense*) is also considered a major problem at several sites, e.g., along the Flint River (Rickard 2021, pers. comm.). Introduction and spread of non-native invasive species often occur with urbanization (McKinney 2002, p. 888) and other types of adjacent land uses, such as agriculture and timber harvest. Shifts in forest structure and hydrology may increase the propensity for invasive plants to invade relict trillium sites. Japanese honeysuckle has been documented as negatively impacting relict trillium survival through resource competition (Caspary and Rickard 2016, p. 64). Carolina cherry laurel (*Prunus caroliniana*), a native species, has also been mentioned as a management concern for relict trillium occurrences in South Carolina (Bradley 2021b) because it also can invade disturbed relict trillium habitat.

Feral hogs (*Sus scrofa*) occur throughout the Southeast and on most public conservation lands, where they are considered non-native invasive species (Edwards et al. 2013, p. 362). Hogs can negatively affect almost all aspects of ecosystem structure and function (Jolley et al. 2010, p. 519) and are known to have significant impacts to native plant communities both directly (through consumption) and indirectly through rooting and soil disturbance (Waddell 2006, p. 9; Heckel and Leege 2007, p. 49; Barrios-Garcia and Ballari, 2012, pp. 2284-2293). Hogs can be extremely destructive to vegetation, particularly in wetter areas where they root around and severely disturb the soil and ground cover over large areas (Edwards et al. 2013, p. 362), as well as localized increases in runoff and sedimentation from upslope foraging and rutting (Figure 12). Impacts to relict trillium from feral hogs have been documented on 48 sites, although substantial and extensive damage was observed at only 8 (10 percent) of relict trillium sites.

Figure 12. Extensive hog damage at a relict trillium site. Credit: U.S. Fish and Wildlife Service.

3.3 Disease and Predation

3.3.1 Disease

Disease has been reported to affect one relict trillium site at Fort Benning Army Installation (Fort Benning) (Service 2009, p. 55). Plants had lesions on the leaves apparently caused by the fungus *Ciborinia trillii* as tentatively identified by Dr. Lori Carris of Washington State University. However, this has not been confirmed and no new information is available.

3.3.2 Predation

Over the last century, white-tailed deer (*Odocoileus virginianus*) population numbers have increased substantially (Horsely et al. 2003, p. 1). White-tailed deer can be a major threat to endangered and threatened plants in the Southeast (Miller et al. 1992, entire) including impacts to species density, diversity, and composition and plant development (Horsely et al. 2003, p. 113). White-tailed deer are generalist herbivores that feed on a variety of herbaceous and woody species of plants, but they may show preference for some species (Wakeland and Swihart 2009, p. 96). Further, habitat fragmentation from urbanization and other land use changes may increase herbivory by deer. White-tailed deer herbivory has been documented to significantly reduce the relative growth and reproductive success in relict trillium (Thompson 2007, pp. 57-58; Leege et al. 2010, pp. 438-439).

Populations of relict trillium have been reduced due to deer herbivory at the Savannah River Bluffs Heritage Preserve in Aiken County, South Carolina (Bradley 2019, p. 24) and Montezuma Bluffs Wildlife Management Area (WMA) in Macon County, Georgia (Rickard 2021, pers. comm.). Because of intense public recreation at the preserve, deer harvest is not permitted within the Savannah River Bluffs Heritage Preserve. In addition, neighbors from dense developments around the preserve feed deer (Bradley 2019, p. 24). The abundance of food and lack of hunting has resulted in a very dense deer population and created a depauperate, almost barren herbaceous layer at the site.

Indirect impacts of deer density and herbivory, such as competition and facilitation of browse-resilient species, are a concern for deer forage species (Horsely et al. 2003, p. 114). A 10-year study of deer impacts on vegetation in hardwood forests found increased deer populations resulted in reduced plant species diversity and increased browse-resilient plants or plants avoided by deer (Horsely et al. 2003, p. 115). At this time, the indirect impacts of deer herbivory on relict trillium are unknown; however, direct impacts from deer herbivory have been documented at 78 (99%) of relict trillium sites and is substantial or extensive at 38 (48 percent) of sites. Further, deer browsing may be even more widespread than documented because deer may completely remove the above ground portion of individual plants making it difficult to confirm impacts from browsing.

In addition to white-tailed deer, herbivory from a cutworm caterpillar (*Cerastis tenebrifera*) has been documented at a site near the Savanah River Bluffs and has been reported as one of the three main threats at this site along with white-tailed deer and non-native invasive plant species (Gordon 2009, entire). The cutworm has not been verified to occur at other relict trillium sites, but leaf and stem damage consistent with evidence at the Savannah River Bluff sites has been documented at one translocation site in Harris County, Georgia (Elmore and Caldwell 2017, entire). In general, the cutworm may be localized at some sites but is not known to be a significant factor for relict trillium across its range.

3.4 Climate Change

In the southeast United States, several climate change models have projected more frequent drought, more extreme air temperatures, increased precipitation (i.e., increased flooding and erosion), and more intense storms (e.g., frequency of major tornados) (Burkett and Kusler 2000, p. 314; Klos et al. 2009, p. 699; IPCC 2023, pp. 5-14). When considering future climate projections for temperature and precipitation where relict trillium occurs, warming is expected to be greatest in the summer, which is predicted to increase drought frequency, while annual mean precipitation is expected to increase slightly, leading to a slight increase in flooding events (Alder and Hostetler 2013, unpaginated; IPCC 2014, entire; USGS 2021 unpaginated).

Within mixed hardwood forests where the species occurs, drought conditions due to higher temperatures and variable precipitation could impact resources (i.e., soil moisture and nutrients) required for relict trillium survival, increase the risk of negative effects from flooding and erosion, result in changes to overstory tree composition, and limit the ability of relict trillium persist over time. Despite the recognition of climate effects on ecosystem processes, there is uncertainty within each model about what the exact climate future for the southeastern United States will be, and there is uncertainty in how the ecosystems and species will respond. Although there are several potential risks associated with long-term climate change as described above, there is uncertainty regarding the how relict trillium will respond to these risks.

3.5 Conservation Efforts

3.5.1 State and Federal Protections

Alabama does not include plants on any protected species lists. Relict trillium is listed as "endangered" in Georgia and is protected under the Georgia Wildflower Preservation Act, which protects the species on public lands from cutting, digging, pulling, or removing unless the Georgia Department of Natural Resources has authorized such acts (Georgia Code 2015). In South Carolina, the South Carolina Nongame and Endangered Species Conservation Act of 1974 covers only animals and provides no protection for plants on any lands in South Carolina (South Carolina Code 1974). However, the South Carolina State Heritage Trust program does maintain a list of "Species of Concern" thought to be rare, declining, or their population status is unknown, including relict trillium. Furthermore, relict trillium is included in State Wildlife Action Plans (SWAPs) in Alabama (included as a "Plant of Conservation Concern;" Alabama Department of Conservation and Natural Resources 2016, p. 451), in Georgia (a "High Priority Plant;" Georgia Department of Natural Resources 2015, p. 152), and in South Carolina (a "Plant of Concern;" South Carolina Department of Natural Resources 2015, pp. 2-9). Although SWAPs do not compel specific conservation actions or guarantee funding of such actions for relict trillium, inclusion within SWAPs serves to highlight and focus attention on the conservation needs of this species and its habitat especially on protected lands (see below).

The ESA does not provide protection for listed plant species unless there is a Federal nexus. Therefore, activities on private lands that do not have Federal involvement are not regulated. Because the species is a plant, they are not subject to take, but are subject to some prohibited Acts under Section 9 of the ESA. Plants may not be removed from lands under Federal jurisdiction unless the activities are covered under permitted activities (e.g., Fort Benning, Oconee National Forest), and or remove, cut, dig up, or damage or destroy plants in knowing violation of any law or regulation of any State or in the course of any violation of a State criminal trespass law. Activities that are authorized, funded, or carried out by a Federal agency are also required to consult with the Service as part of Section 7 of the ESA. With regards to relict trillium, transportation projects that are at least partially funded by the Federal Highway Administration or require a Clean Water Act permit through the U.S. Army Corps of Engineers are the most common avenues that Section 7 consultation occurs. The consultation under Section 7 provides an avenue to rescue and relocate plants that will be impacted by those activities or work to minimize impacts on relict trillium.

3.5.2 Land Protection and Management

Protected lands include lands that are state or federally owned, and private land owned or protected by conservation organizations (e.g., conservation easements). These properties buffer against the impact of habitat loss and modification due to land use changes. In addition, populations occurring on protected lands are more likely to receive conservation management, such as white-tailed deer hunting and non-native invasive species management. Therefore, the impact of non-native invasive plants species and white-tailed deer herbivory may be reduced for populations that occur on protected land.

Currently, 30 percent (32 of 102) of relict trillium sites are located on 20 protected properties (Table 1, Figure 13). The protected properties include a mixture of State, Federal, and Municipal lands, land trusts (conservation easements), and other conservation sites (

Table 1). Two sites currently include active management for relict trillium (Table 2), Fort Benning and Oconee National Forest. Fort Benning includes species monitoring and management in its Integrated Natural Resources Management Plan (INRMP) that is expected to benefit relict trillium (Fort Benning 2021, pp. 869-870). Known sites have been designated as Sensitive Areas where digging and vehicles are not allowed, timber harvesting is not allowed within 61 m (200 ft) of the relict trillium site boundary, and prescribed burning is prohibited. To protect relict trillium from hogs on Fort Benning, Baker Creek, Kendall Creek South, Kendall Creek North, and Randall Creek North sites have been completely fenced. Consistent with the INRMP, the Randall Creek South site will be fenced when a threat from hogs is observed. At the Oconee National Forest, the Forest Plan and Forest Service Manual provide prescribe management that benefits relict trillium, such as implementing prescribed fire under conditions that avoid impacts to relict trillium habitat (Rickard 2021, pers. comm.).

The Southeastern Plant Conservation Alliance (SE PCA) has been working with the Service to prioritize federally listed plant species, promote region-wide planning and management, and select species for pilot project implementation. Funding was allocated to partners in support of on-the-ground conservation activities and outreach efforts for a subset of these species in 2021 and 2022 (Radcliffe 2021, pers. comm.). Specific on-the-ground management activities for relict trillium that were funded and supported through the SE PCA include constructing 50 cages to exclude feral hogs and nine-banded armadillos from patches of relict trillium at the largest, highest quality, and federally protected site in Alabama (in Henry County). Exclusion cage construction and installation were conducted by Arnold Arboretum at Auburn University, on behalf of the Alabama Plant Conservation Alliance. Each cage consisted of a 3’ x 3’ panel of hog wire held off the ground by rebar stakes. Half of the cages were constructed with the hog wire near the ground to prevent armadillos from getting underneath, and half were constructed with the hog wire 6” off the ground to give the trillium a chance to emerge under the wire protected from grazing from above. In South Carolina, funding will be used to complete non-native invasive plant control at the City of North Augusta Riverview Park (in Aiken County) and a few other small municipal holdings (Strickland 2022, pers. comm.).

Table 1. Federal, State, Municipal, Land Trusts and Conservation lands where relict trillium occurs. An asterisk * indicates a conservation land containing multiple relict trillium sites.

State	Ownership	County	Ownership Name
Alabama	Federal	Henry	Walter F. George Lock & Dam (U.S. Army Corps of Engineers)
Georgia	Federal	Muscogee	* Fort Benning Army Base (U.S. Department of Defense)
Georgia	Federal	Jones, Jasper	* Oconee National Forest (U.S. Forest Service)
Georgia	Land Trust	Muscogee	The Nature Conservancy – Kendall Creek Tract
Georgia	Private	Jones	Conservation Easement (Athens Land Trust)
Georgia	Private	Jones	* Conservation Easement (Georgia Land Trust)
Georgia	Private	Jones	Conservation Easement - Legacy Farms Stream Mitigation Bank - (U.S. Army Corps of Engineers)
Georgia	Private	Muscogee, Talbot	* Conservation Easement (The Nature Conservancy)
Georgia	Private	Talbot	Conservation Easement - Flint River Plantation (North) – (Tall Timbers Land Conservancy)
Georgia	Private	Talbot	Conservation Easement - Flint River Plantation (South) – (Tall Timbers Land Conservancy)
Georgia	Private	Talbot	Conservation Easement -Upatoi Stream Mitigation Bank – (The Nature Conservancy)
Georgia	Private	Taylor	Conservation Easement (Georgia Land Trust)
Georgia	State	Bleckley	Ocmulgee Wildlife Management Area and Public Fishing Area (GA Dept. of Natural Resources)
Georgia	State	Macon	Montezuma Bluffs Wildlife Management Area (GA Dept. of Natural Resources)
Georgia	State	Upson	Big Lazer Creek Wildlife Management Area & Public Fishing Area (GA Dept. of Natural Resources)
South Carolina	Municipal	Aiken	* Riverview Park, North Augusta Greenway, and various water control and sewage management properties (City of North Augusta). Levels of protection and signage vary.
South Carolina	Land Trust	Aiken, Edgefield	Central Savannah River Land Trust – Greystone Preserve
South Carolina	Private	Aiken	* Wetland Avoidance and Minimization Agreement (U.S. Army Corps of Engineers)
South Carolina	State	Aiken	* I-20 Welcome Center (S.C. Dept. of Transportation)
South Carolina	State	Aiken	* Savannah River Bluffs Heritage Preserve (S.C. Dept. of Natural Resources)

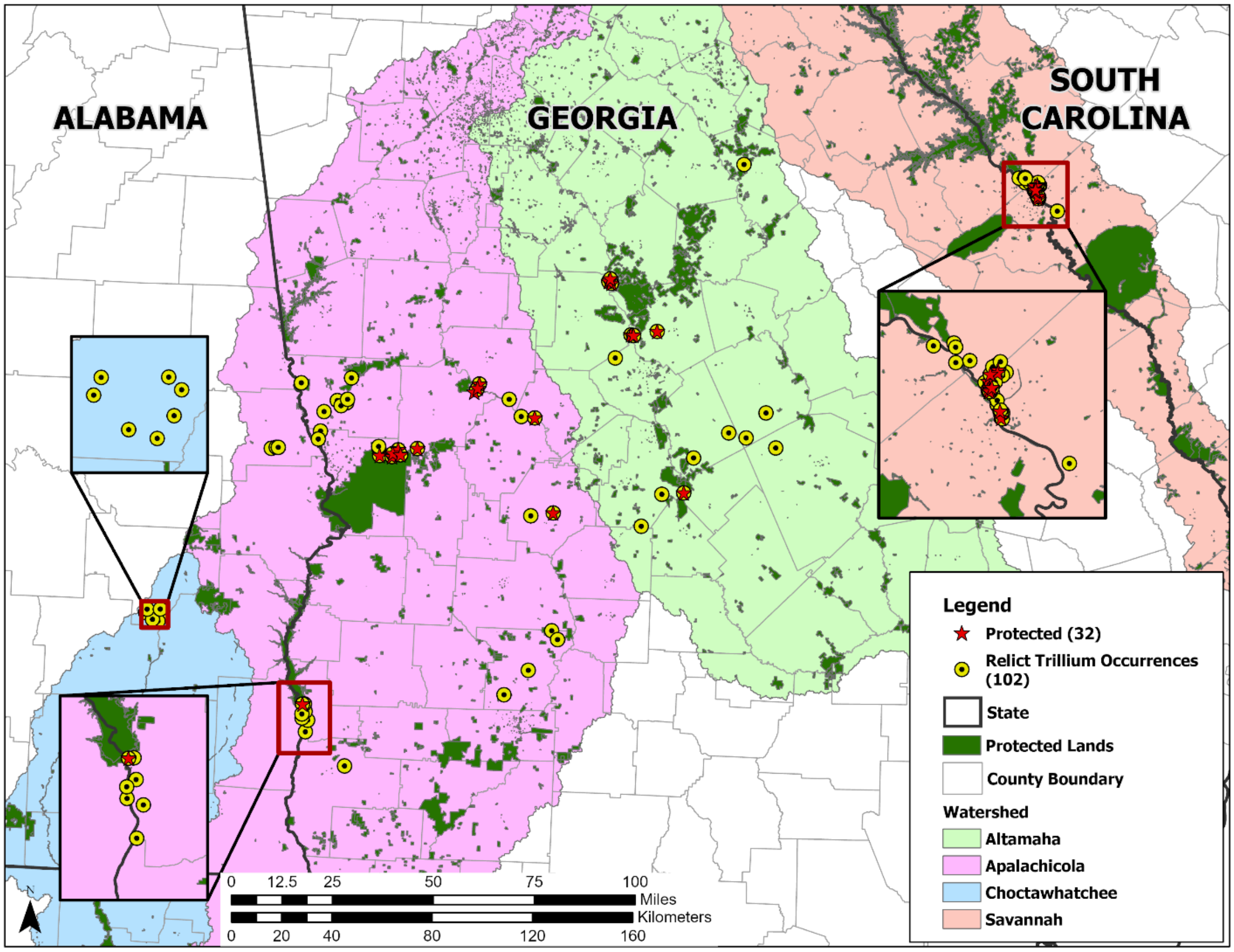

Figure 13. Map of relict trillium occurrences that occur on protected land (red stars) and that do not occur on protected land (yellow and black circles).

Table 2. Habitat management for relict trillium.

Property	**Habitat Management**
Fort Benning	1) Fencing populations, if necessary, from feral hogs. 2) Prohibiting timber harvest within 61 m (200 ft) of the population boundary. 3) Prohibiting digging and vehicles within the sensitive area signs around each population. 4) Prohibiting prescribed burning within the boundaries of the population. 5) Controlling populations of feral hogs by trapping or shooting. (Fort Benning 2021, p.870)
Oconee National Forest	The Forest Plan (2004) and Forest Service Manual provide for the conservation and management of federally listed species, including relict trillium, to contribute to the recovery of listed species. Rickard (2021, pers. comm.) notes the presence of a large population of relict trillium on the Oconee National Forest. A second population was established in Greene County on the National Forest winter 2021 as part of the mitigation plan for a transportation project in Jones County. Portions of the forest are regularly burned in a manner that aims to minimize impacts to suitable habitat and benefits reproduction (Rickard 2021, pers. comm.).

3.5.3 Regional Initiatives

Regionally, most relict trillium-associated sites occur in priority areas identified as part of the Southeast Conservation Adaptation Strategy's *Southeast Conservation Blueprint* (see *http://secassoutheast.org/blueprint*, accessed July 15, 2021, for more information; spatial data available at *https://seregion.databasin.org*, accessed July 15, 2021), which is a regional cooperative and collaborative effort to promote conservation throughout the greater southeastern United States. Relict trillium sites and South Atlantic Conservation blueprint priority areas are illustrated in Figure 14.

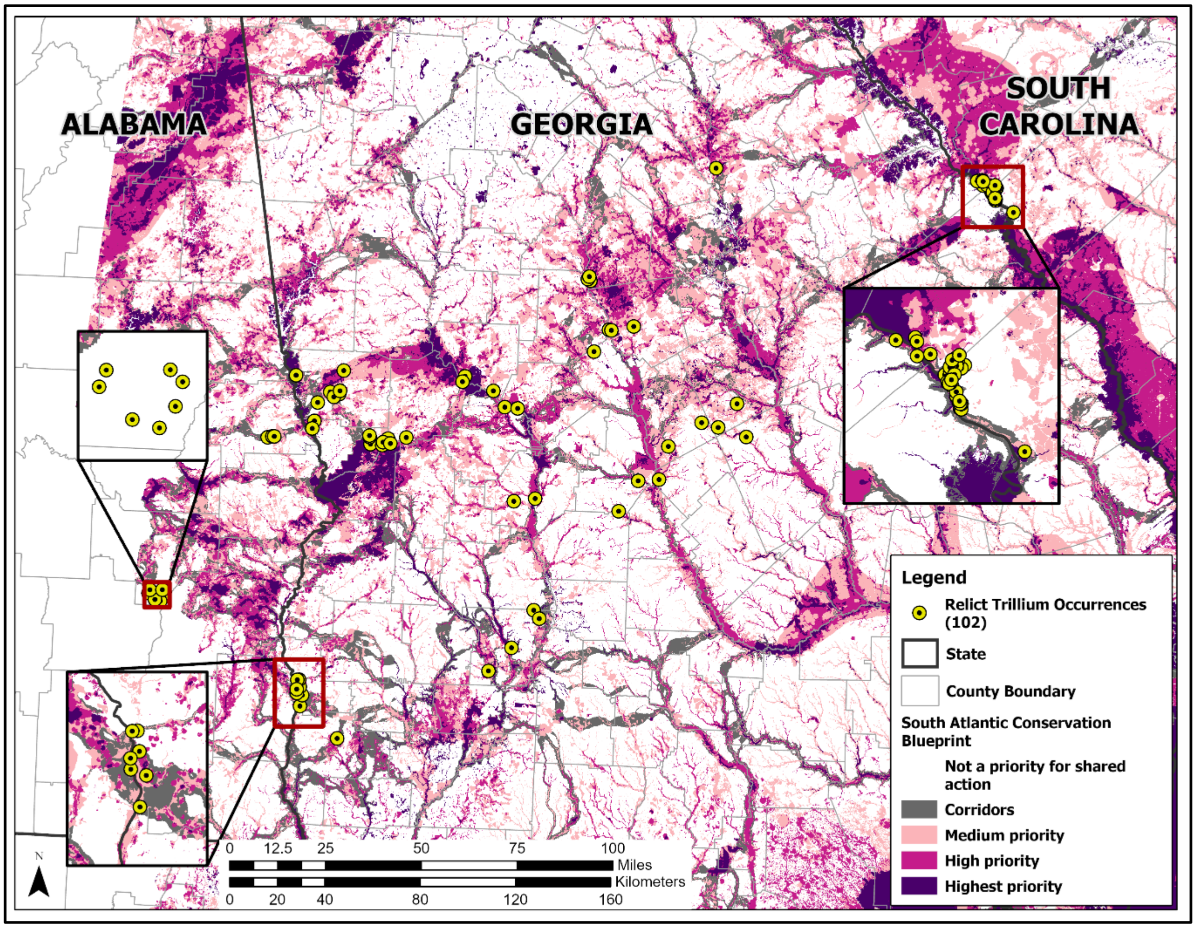

Figure 14. Relict trillium occurrences (yellow circles) and regional priority areas for the South Atlantic Conservation Blueprint.

3.5.4 Conservation Horticulture

Relict trillium has received attention in Georgia from the Georgia Plant Conservation Alliance (GPCA), a statewide network of public and private conservation organizations and agencies formed in 1995 GPCA partners have assisted in the relocation of relict trillium individuals from three locations that were expected to be impacted by project construction to three *in situ* safeguarding sites (Table 3) (Service 2009, pp. 15-20; Service 2018, p. 7; Service 2019, p. 7).

Safeguarding refers to all types of propagation and/or outplanting activities that constitute a conservation strategy of last resort. Specifically, safeguarding refers to various propagation and outplanting activities as they relate to *ex situ* or *in situ* efforts, including reintroductions, augmentations/enhancements, and introductions. Safeguarding sites are not currently considered to be viable for the purposes of species recovery because their recruitment success is uncertain.

Table 3. Summary of GPCA safeguarding actions at three relict trillium occurrences.

***In situ* Safeguarding site**	**Year**	**Number outplanted**	**Activity**
Blanton Creek WMA and Private land with conservation easement (formerly Preserve at Callaway Gardens)	2010	1,274 (664 at Blanton Creek and 610 at former Preserve at Callaway Gardens)	In conjunction with impacts from road construction activities, approximately 1,274 rhizomes of relict trillium were relocated from the Randall Creek North site (at Fort Benning) to two safeguarding sites, Blanton Creek WMA and former Preserve at Callaway Gardens (Elmore and Caldwell 2017, p.3). Over the period from 2010 to 2017, the survival rate at Blanton Creek WMA and former Preserve at Callaway Gardens was 82.2 and 79.4 percent, respectively.
Blanton Creek WMA	2019	44	Relict trillium plants were relocated as part of a GDOT project (P.I. No. 0013601), which consists of the replacement of a bridge over Schley Creek located in Muscogee County on State Route (SR) 219 approximately 10 mi north/northwest of Columbus, Georgia (Service 2018, p. 1). Forty-four plants impacted by the project were relocated to Blanton Creek WMA near the translocated plants from Fort Benning, but spatially separated to facilitate survivorship monitoring. During the most recent survey (2022), 111 relict trillium stems and 5 blooms were observed, representing an increase of 252%. Twenty-five of the documented relict trillium stems were classified as first-year recruits and 1 was classified as a second-year recruit. (GDOT 2022, p. 5).
Oconee National Forest	2020	300	Relict trillium plants were relocated as part of another GDOT project (P.I. No. 370860-), which consists of the replacement of the County Road (CR) 28/Howard Roberts Road bridge over Walnut Creek, located approximately 4.7 mi west of Clinton, Georgia in Jones County (Service 2019, p.1). The plants impacted by the project were collected and held at the State Botanical Garden before being transplanted to a permanent site within Oconee National Forest in late 2021.

3.6 Synergistic Effects

In addition to impacting relict trillium individually, it is likely that several of the above summarized factors are acting synergistically or additively on the species. The combined impact of multiple negative influencing factors is likely more harmful than a single negative factor acting alone. In the future, drought projections could lead to forest conversions, which would result in poorer habitat conditions for populations and reduced reproductive success. When sufficient habitat buffers are not maintained, adjacent land uses (such as urbanization, agriculture, and timber harvest) can fragment habitat and increase the potential for non-native invasive plant species to disperse into native habitats. These changes in land use adjacent to populations, particularly conversions to agriculture or urbanization, will likely result in increased non-native invasive species occurrence and pressure from white-tailed deer browse. Although not well understood some factors may also have negative influences on the native ants that are the primary seed dispersers. Synergistic effects among demographic, environmental, and genetic stochasticity in small populations can yield much higher risks of extirpation than would be apparent on genetic grounds alone.

3.7 Summary of Factors Influencing Viability

We reviewed and summarized the factors that could be affecting the viability of relict trillium (Figure 10). Of these, the primary negative influencing factors currently impacting the viability of relict trillium are: (1) habitat destruction and modification, including urbanization and land use change; (2) non-native invasive species; (3) impacts to hydrology; and (4) herbivory from white-tailed deer browse. Relict trillium and its habitat are directly lost from land use change associated with urbanization, transportation infrastructure, and conversion to agricultural and silvicultural uses. In addition, indirect and edge effects from these adjacent land uses can alter habitat hydrology and forest structure and degrade habitat quality (increased non-native invasive species and deer herbivory), especially when habitat buffers are lost. Also, the future climate prediction of increased variability of precipitation may reduce the resiliency of populations to compete with more stress tolerant plant species.

CHAPTER 4: CURRENT CONDITION

In this chapter, we consider the relict trillium's historical distribution, its current distribution, and what the species needs for viability. We first define populations of the species. Next, we characterize the needs of the species in terms of population resiliency and species' representation and redundancy (the 3Rs). Finally, we estimate the current condition of relict trillium using demographic and habitat factors used to characterize the 3Rs.

4.1 Population Delineation

The Natural Heritage Programs for Alabama, Georgia, and South Carolina collect information on occurrences of rare plants, animals, natural communities, and animal assemblages. Collectively, these are referred to as "elements of natural diversity" or simply as "elements." Locations of these elements are referred to as "element occurrences" (EOs). In recent years, NatureServe and its member Natural Heritage Programs have devised mapping standards to balance the need for fine-scale, highly site-specific EOs (required for monitoring and management) with the need to aggregate these records in meaningful units of conservation interest that may approximate biological populations (NatureServe 2020, entire).

Data for relict trillium EOs assessed in this SSA Report were provided by State Natural Heritage Programs, including Alabama Natural Heritage Program (ALNHP 2021), South Carolina Heritage Trust Program (SCHTP 2021; for South Carolina the term Object ID is synonymous with EO), and Georgia Natural Heritage Inventory Program (GNHIP 2021), as well as from supplemental data and personal communication with Bradley (2021b, 2021c, and 2022), Johnson (2021), Kruse and Milly (2022, pers. comm.), Milly (2021a and 2021b), Sabo (2021), Schotz and Diamond (2021, pers. comm.), and Thornton (2021). Field assistance was also provided by the Atlanta Botanical Garden and Auburn University.

The number of EOs provided by the State Natural Heritage Programs were 100: 13 from Alabama; 51 from Georgia; and 36 from South Carolina. In two instances, involving the state of Georgia (EO # 6 [Talbot County] and EO #9 [Clay County]), occurrences within the same EO were located further apart than the 1km distance used to separate and delineate populations (explained in more depth in subsequent paragraphs). Consequently, we separated each of these EOs into two distinct EOs, bringing the total number of EOs from Georgia to 53, and the range-wide total number of EOs for the species to 102.

Level of information and age of the EO data varied (Table 4). Almost 80 percent of the EOs were considered current, defined as any EOs observed between the years 2002-2021 (less than 20 years old). More than half the EOs (55 percent) were visited in 2021. EOs last observed prior to the year 2002, of which there were 15, are considered historical or extirpated. Historical EOs are those that are possibly extirpated due to unsuccessful searches or more than 20 years since last observed but still there is some hope of rediscovery. Extirpated are those that are believed to be eliminated due to loss of habitat or other impact (e.g., poaching). One of the 15 EOs is known to be extirpated in South Carolina due to urbanization. There were also five EOs known to be extant and observed within the last 20 years but for which there were no additional data available about the EO's current status or size. Additionally, there were three (3) EOs which represented translocated plants moved from development sites intended to safeguard the original source population genetics in the wild (*in situ*) as a conservation measure. The 23 EOs considered historical, extirpated, safeguarded, or with missing or unreliable data were excluded from this analysis. The number of EOs treated as current for this SSA is 79 [102-23 = 79], representing 78 percent of all EOs; with 12 from Alabama, 38 from Georgia, and 29 from South Carolina.

Table 4. Summary of occurrences by state. Current – visited within last 20 years, Historical (or Extirpated) – last visited more than 20 years ago; Safeguarded – translocated plants; No Data – no EO information available.

EO Status	**Alabama**	**Georgia**	**South Carolina**	**Total**	**%**
Current – Visited (in 2021)	7	20*	29	56	55%
Current – Not Visited (in 2021)	5	18	0	23	22%
Historical (or Extirpated)	1	11	2 (1)	15	15%
Safeguarded	0	3	0	3	3%
No Data	0	1	4	5	5%
Total	13	53	36	102	100%

* Includes two State of Georgia EOs (EO # 6 [Talbot County] and EO #9 [Clay County]) that were each separated into two EOs.

We delineated relict trillium population units using NatureServe's Habitat-based Plant Element Occurrence Delimitation Guidance (NatureServe 2020, p.1). For each relict trillium EO (and Object ID for South Carolina), we used NatureServe's decision tree to determine the separation distance for the purpose of coalescing individual occurrences into single populations (NatureServe 2020, p.13). Though occasionally found in floodplains, relict trillium populations primarily occur in rich, mixed deciduous forests on slope areas and dispersal by water is rare (Gonzales and Hamrick 2005, p. 307), so only terrestrial portions of the decision tree were used. Furthermore, our ability to evaluate intervening habitat between any two EOs was limited. Therefore, we used the most conservative 1-km (0.62 mi) separation distance rule to delineate populations, noting that situations involving dispersal barriers could result in population delineations at even shorter distances. To apply this separation distance, we created a 0.5-km (0.31-mi) buffer around each EO and merged EOs into populations where these buffers intersected. This resulted in some isolated EOs being treated as distinct populations, while other populations are aggregates of several geographically clustered EOs (Figure 15). In situations where two buffered EOs intersected but were separated by one of the major rivers within the range, they were considered separate populations. Gonzales and Hamrick (2005, pp. 312-313) found that the Chattahoochee River appeared to be a barrier for pollen and seed dispersal based on the magnitude of genetic divergence between populations located on the east and west sides of the river. The major rivers impacting population delineation for this SSA were the: Chattahoochee (Apalachicola watershed), Flint (Apalachicola watershed), Ocmulgee (Altamaha watershed), and Savannah (Savannah watershed). In all, we delineated 61 population units from 102 EOs distributed across the range of relict trillium (Figure 15). There are 12 populations in Alabama, 45 populations in Georgia, and 4 populations in South Carolina. Of the 61 populations, 44 (72 percent) are considered current (visited in the last 20 years, between 2002-2021). The 44 current populations are assessed in the Current and Future Condition analyses. The remaining 17 populations [61- 44 = 17] representing the historical, safeguarded, and no data/unreliable data EOs are not assessed for resiliency due to insufficient data, although, we present data for these populations in various Figures, Tables, and Appendices because they inform the historical and current range and distribution of the species. Of the 44 current populations, there are 11 populations in Alabama, 31 populations in Georgia, and 2 populations in South Carolina (Table 5).

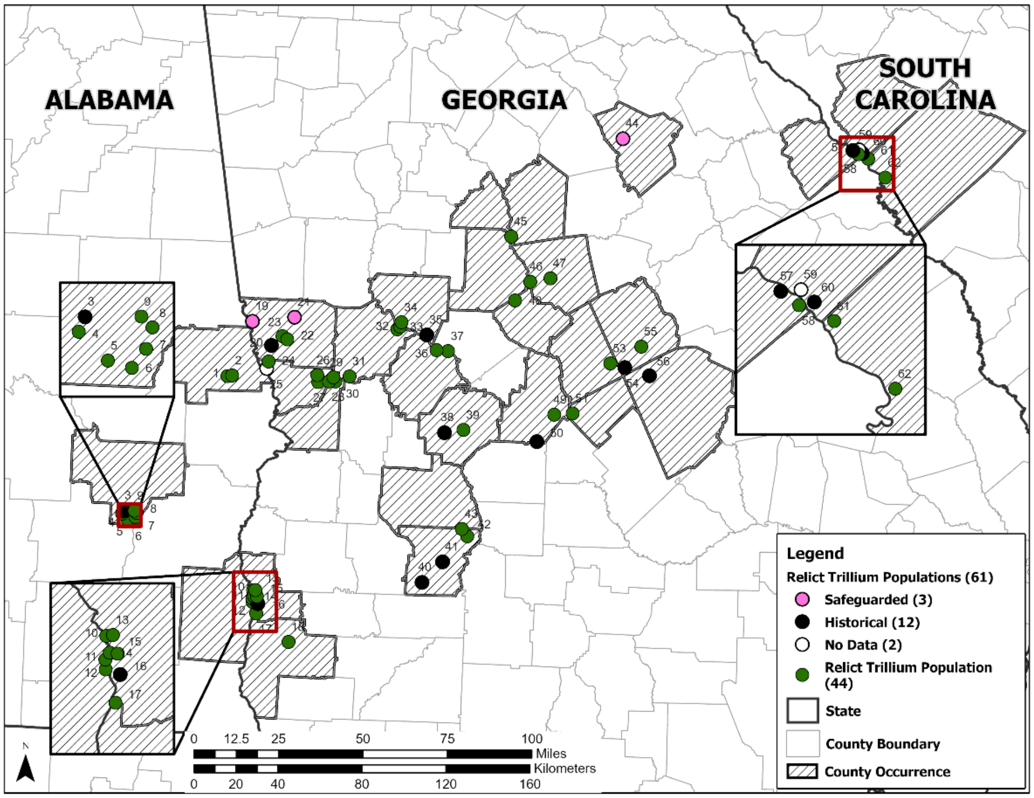

Figure 15. Relict trillium populations (61) in Alabama, Georgia, and South Carolina. Populations were buffered in this figure to enhance visibility.

Table 5. Summary of relict trillium populations by state. Current – visited within last 20 years, Historical – last visited more than 20 years ago; Safeguarded – translocated plants; No Data – no EO information available.

Population Status	**Alabama**	**Georgia**	**South Carolina**	**Total**	**%**
Current – Visited (in 2021)	7	17	2	26	43%
Current – Not Visited (in 2021)	4	14	0	18	29%
Historical	1	10	1	12	20%
Safeguarded	0	3	0	3	5%
No Data	0	1	1	2	3%
Total	12	45	4	61	100%

4.2 Methods for Estimating Current Condition

For the purpose of this assessment, we defined viability as the ability of relict trillium to sustain populations in rich mixed deciduous forested slopes, bluffs, and floodplain ecosystems over time. Using the SSA framework (Chapter 1), we described viability of relict trillium by estimating the current condition (this Chapter) and predicting the future condition (Chapter 5) of factors (modeled at 40- and 60-year time intervals) used to assess resiliency, representation, and redundancy.

4.2.1 Population Resiliency

Each population of relict trillium needs to be able to withstand, or be resilient to, stochastic events or disturbances (e.g., drought, flooding, fluctuations in seed viability, etc.). Therefore, we assessed the resilience of each population by synthesizing the best available information about demographic and habitat conditions from survey data (Appendix B and Appendix C).

Based on relict trillium needs (Chapter 2) and the factors influencing the viability of the species (Chapter 3), the following set of four demographic and habitat condition factors was developed to assess the current overall resilience of each population.

(1) Population Abundance - number of individuals (measured by the number of stems) within a population,
(2) Population Reproduction - amount of reproductive effort within a population,
(3) Habitat Structure - condition of native intact canopy, especially overstory canopy and,
(4) Habitat Threats - factors negatively influencing habitat condition.

For each condition factor, four condition class definitions were developed and assigned a score (Table 6 and Table 7). Additionally, a relative importance weight was assigned to each factor (Table 8). The relative importance weights were informed by responses to expert elicitation questions (Bradley 2021a, pers. comm.; Diamond 2021, pers. comm.; Goertzen 2021, pers. comm.; Rickard 2021, pers. comm.; Schotz 2021, pers. comm.) and vetted by a wider working group that included experts from the core team, state natural resource agencies and the Atlanta Botanical Garden. Using the demographic and habitat data acquired from the State Natural Heritage Programs, an overall population resiliency score was calculated for each population by applying the demographic and habitat definition - score matrix (Table 6 and Table 7) and relative importance weights (Table 8). The following sections provide additional details on the demographic and habitat definition matrix and relative abundance weights.

Table 6. Demographic and habitat factor definitions and condition class (score) matrix used to estimate the current resiliency for 44 relict trillium populations. *See Table 7 for further breakdown of the Habitat Structure factor.

Resiliency Condition Class (Score)	**Demographic: Abundance: Number of Individuals**	**Demographic: Reproduction: Flowering, or Fruiting, or Recruitment (% within or of population)**	**Habitat Structure ***	**Habitat Threat: Invasive Plants**	**Habitat Threat: Feral Hog Damage**	**Habitat Threat: Deer Browse**	**Habitat Threat: Hydrologic Impacts**
High (4)	>2000 individuals	Flowering, or Fruiting; or Recruitment (>10%)	Structure evaluation (see Table 7)	No evidence of invasive plant species (0% -trace)	No evidence of hog damage or activity (0% -trace)	No evidence of deer browse (0% -trace)	No evidence of severe erosion, scour, or hydrological alterations (0%-trace)
Moderate (3)	501-2000 individuals	Flowering, or Fruiting; or Recruitment (6-10%)	Structure evaluation (see Table 7)	Some evidence of invasive plant species (1-5%)	Some evidence of hog damage or activity (1-5%)	Some evidence of deer browse (1-5%)	Some evidence of severe erosion, scour, or hydrological alterations (1-5%)
Low (2)	101-500 individuals	Flowering, or Fruiting; or Recruitment (2-5%)	Structure evaluation (see Table 7)	Moderate evidence of invasive plant species (6-20%)	Moderate evidence of hog damage or activity (6-20%)	Moderate evidence of deer browse (6-20%)	Moderate evidence of severe erosion, scour, or hydrological alterations (6-20%)
Very Low (1)	≤ 100 individuals	Flowering, or Fruiting; or Recruitment (< 2%)	Structure evaluation (see Table 7)	Extensive evidence of invasive plant species (>20%)	Extensive evidence of hog damage or activity (>20%)	Extensive evidence of deer browse (>20%)	Extensive evidence of severe erosion, scour, or hydrological alterations (>20%)

Table 7. Habitat Structure definitions (percent within population) and condition class (score) matrix used to estimate the current resiliency for 44 relict trillium populations.

Resiliency Condition Class (Score)	**Overstory**	**Midstory**	**Shrub Layer**	**Groundcover**
High (4)	Extensive (>75%)	Some (≤ 25%)	Some (≤ 25%)	Some (≤ 25%)
Moderate (3)	Substantial (51-75%)	Moderate (26-50%)	Moderate (26-50%)	Moderate (26-50%)
Low (2)	Moderate (26-50%)	Substantial (51-75%)	Substantial (51-75%)	Substantial (51-75%)
Very Low (1)	Some (≤ 25%)	Extensive (>75%)	Extensive (>75%)	Extensive (>75%)

Table 8. Relative importance weight for each demographic and habitat condition factor.

Condition Factor	**Relative Importance Weight**
Population Abundance	33%
Population Reproduction	17%
Habitat Structure	17%
Habitat Threats	33%
Total	100%

Demographic Factors

The two demographic factors considered for relict trillium were: (1) population abundance; and (2) population reproduction. Relict trillium needs multiple individuals to reproduce and survive over time to replace individuals that have died in a population (i.e., avoid a net loss or negative growth rate). Relict trillium's reproductive success relies on cross-pollination. Small, isolated populations are less likely to be visited by pollinators due to the limited resources available to pollinators (Waddell 2006, p. 10). Therefore, the number of individuals per population (Abundance), and the presence of individuals in a reproductive phase (e.g., flower, fruiting, or recruitment, Figure 16) within a population (Reproduction) were the demographic factors we considered for assessing population resiliency. Abundance was considered twice as important as reproduction, because abundance can influence reproduction and recruitment. Therefore, the Abundance factor was assigned a relative importance weight of 0.33 and Reproduction was assigned a relative importance weight of 0.17 (Table 8). Prior to data collection efforts for the 2021 field season, resiliency condition classes for the demographic factors were developed through expert elicitation (Bradley 2021a, pers. comm.; Diamond 2021, pers. comm.; Goertzen 2021, pers. comm.; Rickard 2021, pers. comm.; Schotz 2021, pers. comm.).

For the **Abundance** factor, we developed four resiliency condition classes and assigned each a resiliency score:

- High resiliency (score 4) had more than or equal to 2,000 individuals,
- Moderate resiliency (score 3) had 501-1,999 individuals,
- Low resiliency (score 2) had 101-500 individuals, and
- Very Low resiliency (score 1) had fewer than or equal to 100 individuals.

Although there currently is not a definition for the minimum population size for a self-sustaining population of relict trillium, the Service's most recent 5-year review considered the minimum number for a sustainable population to be 500 individuals (Service 2015, p. 6). Therefore, we used 500 as the break between low and moderate resiliency for abundance (Table 6). Estimated total number of relict trillium stems across the range is 140,000. This estimate is based upon stem counts (or mid-points of stem count ranges) from State Natural Heritage Program records.

For the **Reproduction** factor, we developed four resiliency condition classes and assigned each a resiliency score:

- High resiliency (score 4) had more than 10 percent of the number of stems present, either flowering, fruiting, or as recruitment individuals,
- Moderate resiliency (score 3) had between 6 to 10 percent of the number of stems present flowering, fruiting, or as recruitment individuals,
- Low resiliency (score 2) had between 2 to 5 percent of the number of stems present flowering, fruiting, or as recruitment individuals; and
- Very Low resiliency (score 1) had fewer than 5 percent of the number of stems present flowering, fruiting, or as recruitment individuals (Table 6).

Resiliency condition class scores were assigned on the basis of the highest percent observed among flowering, fruiting, or recruitment individuals. In many cases there was but a single year's worth of observational data available for this SSA. If no data on reproduction were available for a particular population, a Reproduction Score was inferred based on the population size, i.e., a score of 2 was assigned to any population with an Abundance Score of 1 or 2; and a Reproduction Score of a 3 was assigned to any population with an Abundance Score of 3 or 4. This assumes that larger populations were likely to have proportionally larger recruitment. The intent was to avoid a no-data situation which would disproportionately impact overall resiliency scores for populations which were otherwise known to be both extant and current.

Figure 16. Relict trillium recruitment. Credit: U.S. Fish and Wildlife Service.

Habitat Factors

The two habitat factors we considered for relict trillium were: (1) habitat structure; and (2) habitat threats. Habitat structure included degree of overstory tree canopy, as well as lower strata levels of native vegetation (midstory, shrub layer, and groundcover) that can compete for resources and influence the ability of relict trillium to grow, reproduce, and survive. As an early spring ephemeral herb, relict trillium prefers a closed (or nearly closed) deciduous overstory canopy that allows for high light penetration during the early months of emergence and flowering but will also offer protection by leaf-out from direct sun, heat, and desiccation during mid-Spring to early-Summer. Vegetative competition below the overstory canopy level is generally thought to be deleterious with respect to resource competition. To capture the importance of these habitat factors, the following four components of **habitat structure** were assessed (Table 7):

- native overstory tree – trees greater than 5 m in height,
- midstory – woody plants above 3 m and below 5 m in height,
- shrub layer – woody plants below 3 m in height, and
- groundcover vegetation – non-relict trillium graminoids and herbs.

Additionally, we assessed four components of **habitat threats** that negatively impact habitat quality (Table 7):

- presence of non-native invasive plant species,
- presence of deer browsing,
- presence of feral hogs, and
- hydrologic impacts to habitat from land use change.

As described in Chapter 3, non-native invasive plant species compete with relict trillium for resources, such as soil nutrients, water, sunlight, thus slowing or preventing development of individual relict trillium plants. Relict trillium is also susceptible to herbivory from white-tailed deer, limiting the plant's ability to mature and reproduce. Excessive and consistent herbivory over years can reduce plant stores of carbohydrates to a lethal level. Habitat disturbance from feral hogs, including herbivory, rooting, and wallowing, can negatively impact relict trillium both directly and indirectly. Hydrologic impacts, such as erosion and scouring, may be attributable to nearby activities such as runoff from impervious developed surfaces or poor land management activities. These impacts may also result from larger and more extensive urbanization and use activities within the watershed, as well as from more extreme precipitation events resulting from climate change.

For each of the habitat structure components, we developed four resiliency condition classes and assigned each category a resiliency score (

Table 7).

For **overstory** tree canopy component:

- High resiliency (score 4) had deciduous tree canopy cover more than 75 percent.
- Moderate resiliency (score 3) had canopy cover 51 to 75 percent.
- Low resiliency (score 2) had canopy cover 26 to 50 percent; and
- Very Low resiliency (score 1) had canopy cover less than or equal to 25 percent.

For **midstory, shrub, and groundcover** layer components:

- High resiliency (score 4) had cover less than or equal to 25 percent.
- Moderate resiliency (score 3) had cover 26 to 50 percent,
- Low resiliency (score 2) had cover 51 to 75 percent; and
- Very Low resiliency (score 1) had cover more than 75 percent.

A habitat structure score for each population was calculated by averaging the scores of the four habitat structure components (canopy, midstory, shrub, and groundcover). We also evaluated the degree of an evergreen component of the canopy and other vegetative layers. An intact, mature deciduous overstory canopy is an important component of the habitat for relict trillium to maintain soil moisture and help reduce understory competition. However, if the overstory includes higher amounts of evergreen species, sunlight becomes limited during emergence in the spring, negatively impacting reproduction. If the overall evergreen component of the vegetation within the footprint of the site was 20 percent or more (contributed by any single layer or all layers combined) then one (1) resiliency point was subtracted from the habitat structure score to indicate reduced habitat suitability for relict trillium.

For each of the habitat **threat components**, we developed four resiliency condition classes and assigned each category a resiliency score (Table 6):

- High resiliency (score 4) had evidence of impact affecting 0 percent to less than 1 percent of the site,
- Moderate resiliency (score 3) had evidence of impact affecting 1 to 5 percent of the site,
- Low resiliency (score 2) had evidence of impact affecting 6 to 20 percent of the site; and
- Very Low resiliency (score 1) had evidence of impact affecting more than 20 percent of the site.

A habitat threat score for each population was calculated by averaging the scores of all four habitat threat components (invasive plant species, feral hogs, deer browse, and hydrologic impacts). However, if any one of the threat components had a Very Low resiliency (score 1), then an overall habitat threat score of one (1) was assigned to that population (i.e., there was no averaging of all components). This reflects the powerful deleterious effects to relict trillium and its habitat from any single extensive threat, regardless of other threats that may or may not be present.

To estimate overall resiliency for each relict trillium population, demographic and habitat factor resiliency scores (ranging from 1 to 4) were summed after applying the importance weight for each factor (Table 8). After calculating their overall resiliency score, populations were designated to a resiliency condition class using the score ranges presented in Table 9.

The resiliency score for a given population was calculated as follows:

> *Overall Population Resiliency Score* = (Abundance score*0.33) + (Reproduction score*0.17) + (Habitat structure averaged score*0.17) + (Habitat Threat averaged score*0.33)
>
> Notes:
> Habitat Threats: if any one of the threats scored Very Low, then Habitat Threats score was given a one (1) and were not averaged.
> Habitat Structure: if the evergreen component of a site was 20 percent or more, then one (1) point was subtracted from the habitat structure score.

Table 9. Overall population resiliency classes for relict trillium populations and corresponding score ranges.

Overall Resiliency Class	Very Low	Low	Moderate	High
Score Range	< 1.75	1.75 to 2.49	2.50 to 3.24	≥ 3.25

Table 10. Hypothetical example of overall resiliency score calculation (sum of weighted scores) and resiliency class associated with each score using demographic and habitat factors described in Table 6 and
Table 7.

	Abundance	Reproduction	Habitat Structure	Habitat Threats	Overall Resiliency
Score and Calculation	2.00*0.33 = 0.66	2.50*0.17 = 0.425	3.25*0.17 = 0.5525	3.38*0.33 = 1.1154	2.75
Resiliency Class	Low	Moderate	High	High	Moderate

4.2.2 Species Representation and Redundancy

Representation reflects a species' adaptive capacity to respond to changing near-term and long-term environmental conditions and can be characterized by the breadth of genetic and ecological diversity within and among populations. A species' adaptive capacity is essential for viability, as species need to adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269).

We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which might include measures of inter-population genetic diversity). For relict trillium, we have limited information on the genetic diversity within and among all of the populations across the species' range. Relict trillium is known to reproduce infrequently by seeds and by clonal spread, and typically requires five to seven years to reach reproductive maturity but may take as much as ten years or more (Ohara 1989, p. 5). For an herbaceous species, relict trillium is considered to be long-lived, with some potentially living to 100 years old (Chafin 2020, entire). Gonzales and Hamrick (2005, pp. 311-312) observed that genetic diversity and gene flow among populations was relatively low. However, populations with the highest genetic diversity were in the eastern and western extremes of the geographic range (Gonzales and Hamrick 2005, p. 313). Further, Gonzales and Hamrick (2005, p. 312) found associations within major watersheds may be an important factor for shaping the genetic structure in relict trillium, especially for populations separated by the Chattahoochee River. Although relict trillium seed dispersal may be dispersed by water in rare circumstances which may cover larger distances, seed dispersal distances by ants which is assumed to be more common is limited. However, major rivers may serve as important corridors for pollinators to follow (Gonzales and Hamrick 2005, p. 307). This suggests that for an out-crossing species, populations occurring in the same watershed will likely have similar genetic diversity.

Therefore, to understand the representation of relict trillium, we mapped populations across HUC 6 watersheds. We delineated six Representation Units based on major river systems: Altamaha (ALT), Apalachicola East (APE), Apalachicola West (APW), Choctawhatchee (CHO), Savannah East (SVE), and Savannah West (SVW) (Figure 17). Two of the HUC 6 watersheds were divided into east and west units due to the presence of major rivers that likely serve as a barrier to gene flow due to their width. We measured representation as the number of resilient populations within each of the delineated Representation Units.

Redundancy reflects a species' ability to rebound after a catastrophic event. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangal and Tier 1993, p. 1083). Examples of catastrophic events that could impact relict trillium include severe habitat impacts from storm events such as tornadoes, or severe population impacts from disease (e.g., fungus or insects). Having multiple, high resiliency populations can increase the species' ability withstand catastrophic events (Mangal and Tier 1993, p. 1083). Species that are well-distributed across their historical range are considered less susceptible to extinction and more likely to be viable than species confined to a small portion of their range (Carroll et al. 2010, entire; Redford et al. 2011, entire). For relict trillium, redundancy is characterized by having multiple resilient populations within Representation Units and across the species' entire geographic range. In addition, these multiple, resilient populations should also maintain levels of connectivity among them. To determine redundancy, we assessed the number of historical and current relict trillium populations within defined Representation Units and across the species' entire range (historical and current range).

4.3 Current Condition Results

Overall, 102 relict trillium EOs exist range-wide, from years 1939 to 2021 (Figure 7). Using the methods in Section 4.1 above, we delineated 61 relict trillium populations from the 102 EOs (Figure 15). Of these 61 relict trillium populations, 44 are current, 12 are historical (or extirpated), 3 are safeguarded (translocations), and 2 are known to be extant but no data are available to assess population resiliency. After applying the population delineation methods for this SSA, no populations were determined to be entirely extirpated because the one known extirpated EO is included in a population with current EO data. However, there are 12 populations that are considered entirely historical because all the EO data for those populations were last observed prior to 2002 (more than 20 years ago). The historical populations inform the species' historical range and distribution, but resiliency is not assessed because we do not have confidence that these populations are still extant. The safeguarded populations were established as part of translocation efforts to minimize loss of individuals found at sites that were impacted from development (e.g., road widening project). Although some translocated individuals have survived at the new sites, the long-term success of this conservation method has not been fully evaluated and therefore the resiliency of the populations is unclear. Based on this, historical, safeguarded, and the no data populations were not assessed for resiliency.

4.3.1 Current Population Resiliency

Of the 44 current populations of relict trillium, 10 populations were considered to have high resiliency and 12 to have moderate resiliency (50 percent combined) (Figure 17, Table 11). Twenty (20) populations were estimated to have low resiliency and the remaining two (2) populations were estimated to have very low resiliency (50 percent combined). High and moderate resiliency was largely due to high abundance of individuals (more than 500 individuals) with most of these also exhibiting good quality habitat structure (overstory, midstory, shrub and groundcover components). However, 15 populations exhibited significant evergreen component within the habitat which is expected to negatively impact relict trillium habitat quality. All populations had some evidence of non-native invasive plants, feral hogs, deer browsing and/or hydrologic impacts. Extensive evidence of invasive non-native plants and deer browse were the most prevalent habitat threats range-wide and were the primary factors affecting the low to very low resiliency populations. Of the 44 populations, 16 (36 percent) had extensive to substantial impacts from deer browsing and 24 (53 percent) had extensive to substantial impacts from invasive plant species.

Table 11. Summary of relict trillium populations and their resiliency class by state.

Resiliency Classes	**AL**	**GA**	**SC**	**Total**
High	1	9	0	10
Moderate	4	6	2	12
Low	5	15	0	20
Very Low	1	1	0	2
Total	**11**	**31**	**2**	**44**
Historical	1	10	1	12
Safeguarded	0	3	0	3
No Data	0	1	1	2
Total	**1**	**14**	**2**	**17**
Grand Total	**12**	**45**	**4**	**61**

Seventeen of the 44 relict trillium populations occur on protected land (Figure 17, Table 12). Of these protected populations five have high, four have moderate, and eight have low to very low resiliency. In general, protected sites are more likely to have conservation management implemented than not protected sites, although most protected sites are not known to be specifically managed for relict trillium. There are currently two federal sites (Fort Benning and Oconee National Forest) and one site in South Carolina that implement management of hogs, deer, and invasive plants specifically for relict trillium. Bradley (2021a, pers. comm.) has noted that permitted deer hunting has resulted in better understory conditions for another population located on the Greystone Preserve site in South Carolina. Additionally, the State of South Carolina has resources to manage invasive plants on the Savannah River Bluffs property, however deer management strategies are currently limited and mostly ineffective (Bradley 2021a, pers. comm.). Others have indicated that conservation management is not known to occur on sites in Alabama (Goertzen 2021, pers. comm.; Schotz 2021, pers. comm.). Seasonal deer hunting is also allowed as a recreational opportunity on areas managed as Wildlife Management Areas in Georgia where relict trillium occurs, which may provide indirect benefits to the species.

Table 12. Summary of resiliency condition classes for 44 relict trillium populations, noting if the population occurs on protected lands (State or Federal ownership or lands with a conservation easement) or not protected.

Resiliency Classes	**Number of populations**	**Protected**	**Not Protected**
High	10	5 (2 partial)	5
Moderate	12	4 (2 partial)	8
Low	20	7 (2 partial)	13
Very Low	2	1	1
Range-wide total	**44**	**17**	**27**

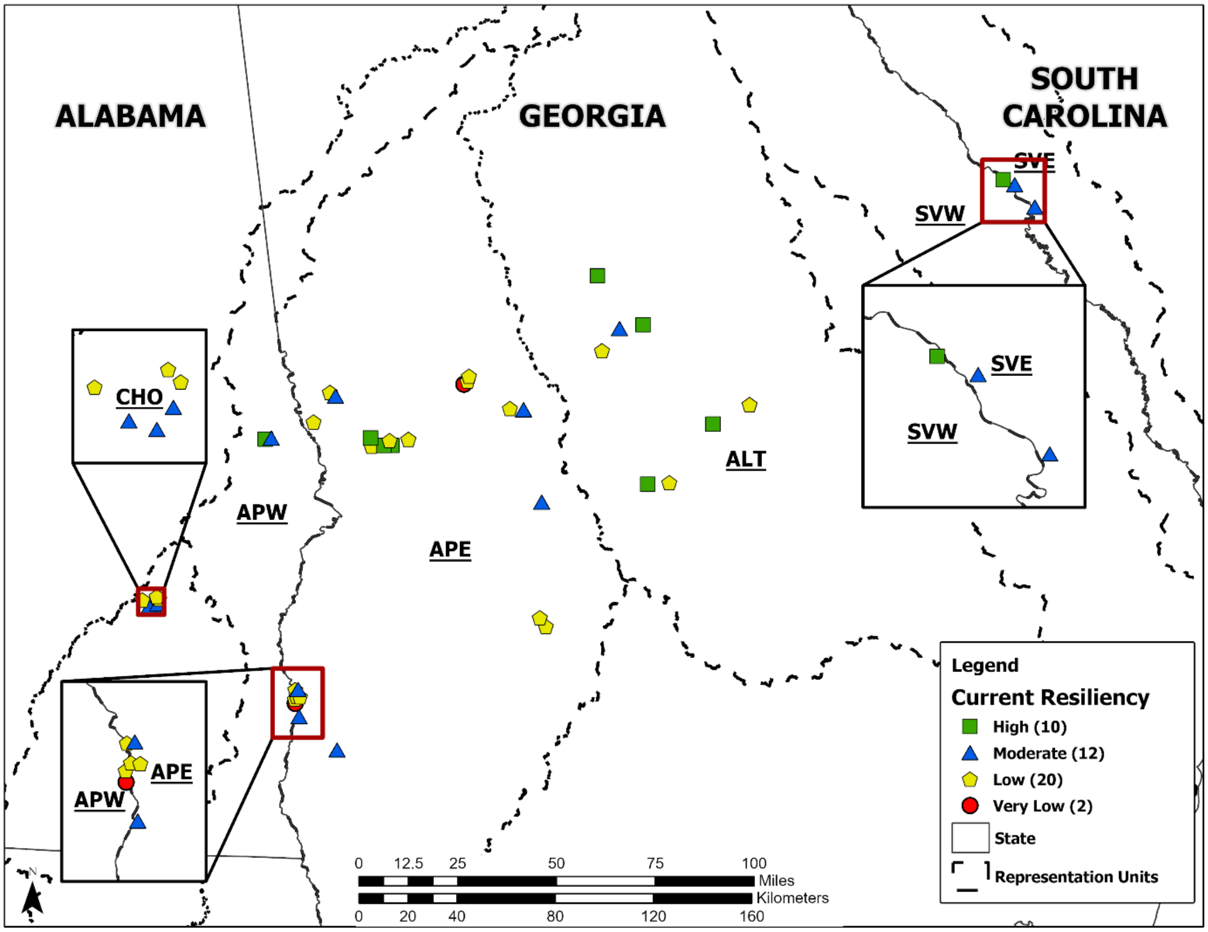

Figure 17. Current condition of 44 relict trillium populations distributed across the six representative units (RUs) in Alabama, Georgia, and South Carolina. Representative Units are indicated by their abbreviation.

The majority (31) of the 44 current populations assessed for resiliency in this SSA occur in Georgia. In total, there are 31 in Georgia, 11 in Alabama, and 2 in South Carolina. Seventeen current populations occur, in whole or in part, on protected lands and 27 are not protected. Across this species' range, none of the known relict trillium populations are considered extirpated. However, the spatial extent of one of the populations in South Carolina has been reduced because one of the EOs that make up that population has been extirpated due to urbanization. Twelve populations are considered historical (not observed in over 20 years). Of the twelve historical populations, all occur on unprotected, private property and surveyors have not been able to access the sites. This information demonstrates the importance of land protection and management to relict trillium on both public and private ownership.

In summary, of the 44 extant relict trillium populations, 10 are characterized with high and 12 have moderate resiliency. The remaining extant populations (22) have low or very low resiliency.

4.3.2 Current Species Representation

To estimate current representation for relict trillium, we summarized the number and resiliency of populations across the six Representation units (RUs) (Figure 17, Table 13). All six RUs have current (extant) relict trillium populations. The APE RU has the majority with 22 populations, followed by the ALT with 8, the CHO with 6, the APW with 5, the SVE with 2, and the SVW with 1. The APE and ALT RUs represent the center of the species geographic range and comprise almost 70 percent (30 of 44) of all the current populations.

All six RUs have at least one high or moderate resiliency population: two are in the APW RU, nine are in the APE RU, three are in the CHO RU, five are in the ALT RU, one is in the SVE RU, and two are in the SVW RU. Populations with the highest genetic diversity are in the western and eastern extremes of the species range (Gonzales and Hamrick 2005, p. 313). The CHO and APW RUs represent the western extent (Alabama populations), each having three and two high to moderate resiliency populations, respectively. The SVE RU represents the eastern extent (South Carolina) and has two moderate resiliency populations.

All six RUs have at least one low to very low resiliency or historical population. Of the populations having low or very low resiliency, most are in the central portion of the range with 13 populations within the APE RU and 3 in the ALT RU. Of the remaining populations with low or very low resiliency, three are in the CHO RU and three are in the APW RU (Alabama populations). All six RUs, except the APW, have at least one historical population.

Currently, relict trillium has 44 populations in varying levels of resiliency occurring in all 6 RUs. However, the number of populations is not evenly distributed across the RUs, putting some RUs at greater risk of loss of representation if populations become extirpated. Specifically, the RUs representing the western (CHO and APW) and eastern (SVE) extents of the range are known to have the highest genetic diversity but have the fewest populations. Given the low to very low resiliency of 22 of the 44 populations (50 percent) and 12 populations are considered historical, the species has reduced representation and therefore may have reduced capacity to adapt to changing environmental conditions.

4.3.3 Current Species Redundancy

To estimate species redundancy, we summarized the number, distribution, and resiliency of relict trillium populations across the six RUs (Figure 17, Table 13). All RUs contain at least two current relict trillium population. The greatest number of current populations (30) and the majority of the high to moderate resiliency populations (14) occur in the central portion of the range (APE and ALT RUs). The fewest number of populations occur in the eastern RUs. The SVW RU has no redundancy with only one high resilient population and the SVE RU has low redundancy with only two moderate resiliency populations. Currently, there are 22 high or moderate resiliency populations distributed across all six RUs.

There has been a reduction in redundancy over time for relict trillium within each RU and across the range. This is highlighted by approximately half (22 of 44, 50 percent) of the current populations having low to very low resiliency. Further, all RUs except the APW RU have historical populations. However, there are 22 high to moderate resiliency populations distributed across the RUs and range of the species. All RUs have at least two high or moderate resiliency populations, except the SVW RU having only one high resiliency population. Therefore, we determined that relict trillium currently has moderate redundancy.

Table 13. Relict trillium Representation Units (RUs), listed from the western to eastern extent of the range, with number of populations and current population resiliency classes. The number of populations that are on protected lands within each RU is indicated in parentheses.

Resiliency Classes	CHO	APW	APE	ALT	SVW	SVE	Total
High	0	1	4 (3)	4 (1)	1	0	10
Moderate	3	1	5 (2)	1 (1)	0	2	12
Total	**3**	**2**	**9 (5)**	**5 (2)**	**1**	**2**	**22**
Low	3	2 (1)	12 (4)	3 (1)	0	0	20
Very Low	0	1	1 (1)	0	0	0	2
Total	**3**	**3 (1)**	**13 (5)**	**3 (1)**	**0**	**0**	**22**
Historical	1	0	6	3	1	1	12
Safeguarded	0	0	2	1 (1)	0	0	3
No Data	0	0	1 (1)	0	0	1	2
Total	**1**	**0**	**9 (1)**	**4 (1)**	**1**	**2**	**17**
Grand Total	**7**	**5**	**31**	**12**	**2**	**4**	**61**

4.3.4 Current Condition Summary

In summary, we assessed relict trillium's current condition based on population resiliency and the species' representation and redundancy using a total 61 delineated populations. Of the 61 populations, 44 were considered current (i.e., extant) and were further assessed for resiliency based on survey data. In our assessment of the current resiliency of these 44 populations, 10 (23 percent) have high, 12 (27 percent) have moderate, 20 (45 percent) have low, and 2 (5 percent) have very low population resiliency (Figure 17, Table 12). High and moderate resiliency was largely due to high abundance of individuals. All populations had some evidence of non-native invasive plants, feral hogs, deer browsing and/or hydrologic impacts. Extensive evidence of invasive non-native plants and deer browse were the most prevalent habitat threats range-wide and were the primary factors affecting the low and very low resiliency populations.

Species representation and redundancy show 22 of 44 current populations exhibit low or very low resiliency and there are an additional 12 historical populations (34 of 61 delineated populations total). Although a trend analysis was not possible with the available data, qualitative and anecdotal information gleaned from state Natural Heritage Program records suggest a decline in both representation and redundancy. However, populations are currently extant with varying levels of resiliency across all six RUs. The high resiliency populations (9) are almost all located in the center of the range in the APE, ALT, and SVW Rus (in the State of Georgia) and 12 moderate resiliency populations are distributed throughout the historical range of the species. The western extent (Alabama populations, CHO and APW RUs) and the eastern extent (South Carolina, SVE RU) represent the populations with the highest genetic diversity but have low redundancy compared to the RUs in the central portion of the range. However, those RUs (CHO, APW, and SVE) contain two to three high to moderate resiliency populations. Therefore, currently relict trillium has some level of adaptive capacity (representation) and ability to rebound after catastrophic events (redundancy).

CHAPTER 5: FUTURE CONDITIONS AND VIABILITY

We have considered what relict trillium needs for viability and the current condition of those needs (Chapters 2 and 4), and we reviewed the factors that are driving the current and future conditions of the species (Chapter 3). We now consider what the species' future condition is likely to be. We apply our future forecasts to the concepts of resiliency, representation, and redundancy to describe the future viability of relict trillium.

5.1 Introduction

To assess the future condition of relict trillium, we have forecasted what relict trillium may have in terms of resiliency, redundancy, and representation under four plausible future scenarios. As outlined in Chapter 3, the primary factors influencing the viability of relict trillium are habitat-based and include habitat degradation or loss resulting from urbanization and land use changes, including conversion to pine plantations and other agricultural uses. We also considered habitat threats (damage or mortality from deer browsing, disturbance from feral hogs, competition from non-native invasive plants, and impacts to hydrology) that are often promoted by urbanization and land use change. In addition, we considered how land protection and conservation management of relict trillium habitats may improve future population resiliency.

Since the main factors influencing the viability of relict trillium are habitat-based, we performed spatial analyses to project changes in urbanization and other land cover within each population over time. We used these projections to develop our scenarios to predict future relict trillium population resiliency. We assessed future resiliency for the 44 current populations but did not assess future resiliency for the historical (12), safeguarded (3), or no data (2) populations.

We considered relict trillium's response to urbanization, land use change, and habitat threats (i.e., non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts) under four plausible future scenarios. Based on the lifespan of the species, reproductive cycle, confidence in models and projections of factors influencing the species' viability, and certainty in predictions of the species' response to those factors, we chose a predictive time horizon of 2040 and 2080. By using these time steps for future predictions, we represented a range of influencing factors that can impact relict trillium over time.

The life span of relict trillium is unknown, though an individual could potentially live for hundreds of years under good conditions. Reproductive maturation age may occur as early as 5 to 7 years. We were reasonably certain we could forecast the response of relict trillium to varying probabilities of urbanization and other land use changes within a predictive time period of 60 years. Therefore, we summarized predicted population resiliency conditions for each scenario at years 2040 and 2080. The time steps began in 2021, as this was the end of our current condition timeframe. Our analysis is limited to four future scenarios, which are representative examples from the potential range of plausible scenarios, and that describe how these factors influence the species and may drive changes from current condition in the future.

5.2 Methods and Scenarios

5.2.1 Urbanization

We used an urbanization (SLEUTH) model to project change in habitat suitability due to urbanization, using projections for the Southeastern U.S. (Terando et al. 2014, entire) at two time steps: 2040 and 2080. Each of these datasets map a baseline of urbanized areas (year 2009) and the expected probability for an area to be urbanized in that decade. When predicting future conditions using the SLEUTH model in all scenarios, we recognize that the projected urbanization may not take place on the specific footprint where relict trillium occurs (particularly for populations with very low abundance), but we expect that effects to the species will occur from urbanization changes within the population unit defined in Chapter 4. Some uncertainty within the population-level SLEUTH model projections is inherent. Therefore, assessments at the population level may be considered generally reflective of the level of threats to relict trillium from loss of suitable habitat and indirect impacts from increased deer browsing, disturbance from feral hogs, competition from non-native invasive plants, and hydrological impacts (see discussion in Chapter 3).

Our assumption for relict trillium is that increased urbanization within a population unit is correlated with habitat loss and indirect impacts will occur from the other factors, such as invasive plants and deer herbivory. We estimated the amount of urbanization that would potentially occur within each population unit based on the SLEUTH model probabilities and simulated habitat suitability for relict trillium under these urbanization projections assuming two levels of urbanization probabilities to capture the full range of future possibilities:

(1) Under the High Urbanization probability, we included all probabilities for an area to be developed.

(2) Under the Status Quo Urbanization probability, we included only those areas that have a probability greater than or equal to 40-50 percent of being developed.

The equation to calculate this future habitat suitability is:

- Current habitat suitability =
- Future habitat suitability = Current habitat suitability * (1 - Probability of urbanization)

We also calculated the percent habitat loss with the equation:

- Percent habitat loss = 1 - (Future habitat suitability / Current habitat suitability)

Within the spatial modeling framework, we defined suitable habitat as the existing population area, including the 0.5 km buffer described in Chapter 4. To forecast future urbanization, we consider future scenarios that incorporate urban growth modeling using an adaptation of the SLEUTH-3r (Slope, Land use, Excluded area, Urban area, Transportation, Hillside area) model (described in Jantz et al. 2010, entire). The SLEUTH model predicts the probability of urbanization and is based on the National Land Cover Database (NLCD) dataset. SLEUTH is a cellular automata model that applies transition rules to the states of a gridded series of cells and, in this case, the transition is that from undeveloped to developed land cover, otherwise known as urbanization (Chaudhuri and Clarke 2013, pp. 1-3), and has been successfully applied worldwide over the last 15 years to simulate urbanization. SLEUTH model predictions for each 60 m × 60 m (197 ft × 197 ft) cell are given as a probability of urbanization, ranging from 0 to 100 percent, and are modeled for each decade from 2010 (baseline) to 2100.

The Southeast Regional Assessment Project Designing Sustainable Landscapes model adjusts the SLEUTH model to simulate patterns of urban expansion that are consistent with spatial observations of past urban growth and transportation networks, including the sprawling, fragmented, "leapfrog" development that has been dominant in the southeastern United States (Terando et al. 2014, p. 2). The model predicts the probability of urbanization but becomes less accurate when downscaled. Therefore, we assessed the extent of potential urbanization on population units but recognize the uncertainty of the projections at the population level based on the resolution of the model. We assessed urbanization in 2040 and 2080 at two probability ranges under a constant rate of urbanization. A range of 40 to 50 percent or more probability of being urbanized (including only those pixels that were "at least as likely to be developed as not") represented a moderate (or status quo) urbanization scenario (Scenarios 1 and 2). A 1 percent or more probability of being developed represented a high urbanization scenario (Scenario 3). Inclusion of areas with a lower chance of urbanization leads to an overall greater area expected to be urbanized; for example, an area with a 20 percent chance of urbanization would be included in Scenario 3 and not in Scenarios 1 and 2. Scenario 4 is the "conservation scenario." In Scenario 4, we anticipate the same probability of urbanization as Scenarios 1 and 2 (moderate or status quo urbanization) but assume that relict trillium populations that are located on protected lands are actively managed for the benefit of the species (e.g., fencing to prevent deer herbivory and/or removal of invasive species).

To forecast the effect of urbanization on relict trillium in the future, SLEUTH model outputs were used to assign adjustments to current resiliency scores for each relict trillium population. First, we calculated the predicted percent change from 2009 in the two urbanization probabilities for each population unit at each time step (2040 and 2080), where predicted changes from suitable habitat to developed occurred in the model. We used 2009 as the current year for urbanization because this was the starting point for the SLEUTH model and future years are based on model outputs. We then applied a scale to adjust the resiliency score for each population unit based on percent increase in urbanization (Table 14). Ranges for predicted increases are based on previous predictive modeling and input from the team of species experts. Bins are not equally distributed to reflect that greater levels of development will negatively impact populations disproportionately. Predicted increase in urbanization of 0.1 – 5 percent within a population unit was considered minimal; therefore, resiliency scores were adjusted by subtracting two tenths (-0.2) resiliency points. Predicted increase in urbanization of 6 – 10 percent within a population unit was considered low; therefore, resiliency scores were adjusted by subtracting four tenths (-0.4) resiliency points. Moderate (11 – 39 percent) and high (40 –

100 percent) predicted percent increase in urbanization within a population unit were adjusted by subtracting six tenths (-0.6) and eight tenths (-0.8) resiliency points, respectively. Model predictions to not account for whether or not a population is located on protected lands because adjustments for them are addressed separately and indirect impacts from urbanization may not artificial boundaries. Resiliency scores for relict trillium population units with no predicted urbanization were not adjusted. These urbanization adjustment scores were then applied along with the land use change and impacts from habitat threats described in the next sections to calculate the final future resiliency scores for each relict trillium population at each time step. Predicted urbanization output from the SLEUTH model and adjusted scores assigned to each population unit under each scenario for year 2040 and for year 2080 are in Appendix D.

Table 14. Percent urbanization increase adjustment scale and population resiliency adjustment scores.

Percent Urbanization Increase Adjustment Scale	**Resiliency Adjustment Score**
No urbanization predicted	0
0.1–5%	-0.2
6–10%	-0.4
11–39%	-0.6
40–100%	-0.8

5.2.2 Climate and Land Use Change

In order to assess land use change for multiple time steps over a large geography, we evaluated the USGS Earth Resources Observation Science Center FORE-SCE (FOREcasting SCEnarios) model, which projects land use changes for each land use type (Sohl et al. 2018, entire). The FORE-SCE model generates a range of spatially explicit land use projections from 1992 through 2100 and incorporates multiple datasets related to growth, including climate change, urban development, agriculture development, and other socioeconomic pressures. These factors are evaluated in relation to four climate change scenario families (from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios; Nakicenovic et al. 2000, entire). When viewing future conditions though the FORE-SCE model in all scenarios, we recognize that the projected land use change may not take place on the specific footprint where relict trillium occurs (particularly for populations with very low abundance), but we expect that effects to the species will occur from land use changes within the population unit. No model exists at the scale or resolution to predict change at the precise location of relict trillium individuals within the population, so some uncertainty within the population-level FORE-SCE model projections is inherent. Therefore, assessments at the population level may be considered generally reflective of the level of threats to relict trillium from loss of suitable habitat from land use change and indirect impacts from increased deer browsing, disturbance from feral hogs, competition from invasive plants, and hydrological impacts. A modeled loss of all suitable habitat within a given population unit should not be construed as an actual loss of the population but rather an indication of the level of potential future impact.

The FORE-SCE models are not explicitly linked to representative concentration pathways (RCPs or greenhouse gas concentration trajectory), with RCPs as plausible pathways toward reaching a target radiative forcing (i.e., the difference between sunlight absorbed by the Earth and energy radiated back to space) and generally understood as climate change scenarios. However, the FORE-SCE models do incorporate these climate change scenarios in storylines that also consider human population increase, technological, and socioeconomic drivers (the demand allocation component of the model). The FORE-SCE model incorporates protected areas, forest stand age, and USGS-determined spatial characteristics into the spatial allocation component of the FORE-SCE model. The two FORE-SCE projection storylines incorporated in our analysis include the A2 storyline (reflective of RCP 8.5 and a higher emissions scenario) and B2 (reflective of RCP 4.5 and a lower emissions scenario) (Nakicenovic et al. 2000, entire; Sohl et al. 2014, entire). The A2 scenario assumes high economic growth and very high population growth globally and includes the highest rate of urban increase. In general, the projections based on the A2 scenario indicate a loss of suitable habitat of varying degrees. The B2 scenario projections are based on the lowest US population growth and a focus on environmental protections. In general, these assumed patterns underlie a decrease in cropland and an increase in forested habitats, with gains in this land cover types additive through time.

Within the FORE-SCE model, 17 land cover types similar to classes from NLCD are evaluated and projections are characterized by 250-meter spatial resolution (250 m x 250 m [820 ft x 820 ft] pixel or cell size). We chose the deciduous forest and mixed forest land cover classes as representative of the extent of potentially suitable habitat for relict trillium, although we recognize that not all areas categorized as these land cover types offer suitable habitat for relict trillium.

The FORE-SCE model develops annual projections from 2009 to 2100. We evaluated projected changes (loss or gain in the two land types, deciduous forest and mixed hardwood) in suitable habitat predicted by the FORE-SCE model for two Special Report Emissions Scenarios (SRES) (B2/RCP 4.5 and A2/RCP 8.5) at time steps 2040 and 2080. Scenario 1 includes the B2 projections, while Scenarios 2 through 4 include the A2 projections (Table 17).

To forecast the effects of land use change on relict trillium in the future, FORE-SCE model outputs were used to assign adjustments to resiliency scores for each population at each time step (2040 and 2080). We calculated the predicted percent change from 2021 in suitable habitat under the two FORE-SCE scenarios (B2 and A2) for each population at each time step (2040 and 2080) (Appendix E). Then, we applied a scale to adjust the resiliency score for each population based on percent loss of suitable habitat within each population unit (Table 15). Predicted percent loss of suitable habitat of 0.1 to 5 percent within a population unit was considered minimal; therefore, resiliency scores were adjusted by subtracting two tenths (-0.2) resiliency points. Predicted percent loss of suitable habitat of 6 to 10 percent within a population unit was considered low; therefore, resiliency scores were adjusted by subtracting four tenths (-0.4) resiliency points. Moderate (11 to 39 percent) and high (40 to 100 percent) predicted percent loss in suitable habitat within a population unit were adjusted by subtracting six and eight tenths (-0.6 and -0.8) resiliency points, respectively. Resiliency scores for populations with a gain of suitable habitat or no predicted loss of suitable habitat were not adjusted. These land use change adjustment scores were then applied along with the urbanization scores and the habitat threat scores (following section) to calculate the final resiliency scores for each population. Predicted land use change output from the FORE-SCE model and adjustment scores assigned to each population under each scenario for year 2040 and for year 2080 are in Appendix E.

Since the SLEUTH model reflects urbanization and the FORE-SCE model may also reflect loss of suitable habitat as a result of urbanization in limited areas, we recognize the future condition resiliency model may reflect loss of habitat to urbanization under both models. However, we expect urbanization to have effects beyond direct loss of habitat including increase in impervious surface and effect on runoff and flooding and an increase in water demand. Therefore, we determined the result of urbanization reflected in the resiliency scores is appropriate and does not overestimate the effects of urbanization in most cases.

Table 15. Percent suitable habitat change adjustment scale and population resiliency adjustment scores.

Percent Change in Suitable Habitat Adjustment Scale	**Resiliency Adjustment Score**
Gain or no loss	0
0.1–5%	-0.2
6–10%	-0.4
11–39%	-0.6
40–100%	-0.8

5.2.3 Habitat Threats

To project the future condition of habitat threats in relict trillium populations, we considered the same factors as the current condition analysis described in Section 4.2.1. These factors include non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts to habitat from adjacent land uses. In the four plausible future scenarios, we distinguish between the habitat threats likely to occur on protected lands (lands owned by State or Federal agencies or conservation organizations,
Table 1) and the habitat threats likely to occur on non-protected lands.

In Scenarios 1 and 2 (Status Quo), for populations that occur partially or entirely within protected lands (State or Federal agencies or conservation organizations), we assume present habitat threats will continue to impact the species but at a lower level than non-protected sites. We assume that through both time steps (2040 and 2080) habitat will continue to be protected such that habitat structure is maintained and impacts from the various habitat threats (i.e., non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts) are moderated. Therefore, we applied a consistent habitat threat adjustment score (-0.2) to resiliency across both time steps (Table 16).

In Scenarios 1 and 2 (Status Quo), for populations that occur on non-protected lands, we expect impacts from habitat threats will continue at the same rate that has been experienced in the past, increasing over time. In our assessment of future conditions, we have assumed that impacts to habitat structure will be additive (i.e., cumulative shifts in habitat strata (overstory, midstory, shrub, and groundcover)) and habitat threats will continue to increase; therefore, we applied a greater adjustment score in 2080 than in 2040 for populations on non-protected lands across all scenarios (Table 16). Resiliency scores for non-protected populations were adjusted by subtracting four tenths (-0.4) resiliency points in 2040 and six tenths (-0.6) resiliency points in 2080 to project changes in habitat threats.

In Scenario 3 (Increased Impacts), we assumed habitat threats will continue to be moderated on protected lands, therefore, we expect the same level of change in habitat threats for populations on protected lands as described for the status quo scenarios (resiliency adjustment score -0.2) at both time steps. However, on non-protected lands, we expect negative impacts to habitat structure and impacts from habitat threats (i.e., non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts) will be greater than the rate that has been experienced in the past. Therefore, we applied a greater resiliency adjustment score by subtracting four tenths (-0.6) resiliency points in 2040 and six tenths (-0.8) in 2080 (Table 16).

In Scenario 4 (Conservation), we expect similar conditions to Scenario 2, except that all relict trillium populations that are located (entirely or in part) on protected lands are assumed to be actively managed for the benefit of the species (e.g., fencing to prevent deer herbivory and/or removal of invasive species). Therefore, we applied an adjustment score of zero (0), to represent the potential for conservation management to mitigate habitat threats.

Table 16. Habitat threat resiliency adjustment score based on land protection status and future time step.

Time steps	Land Protection Status	Scenario 1 and 2 Adjustment Score	Scenario 3 Adjustment Score	Scenario 4 Adjustment Score
2040/2080	Protected	-0.2	-0.2	0
2040	Non-protected	-0.4	-0.6	-0.4
2080	Non-protected	-0.6	-0.8	-0.6

5.2.4 Future Scenarios and Resiliency Calculations

We assessed future conditions for relict trillium under four plausible future scenarios related to three habitat influences from (1) urbanization, (2) climate-influenced land use change, and (3) habitat threats. The scenarios include: (1) status quo and lower emissions, (2) status quo and higher emissions, (3) increased impacts and higher emissions, and (4) status quo and higher emissions with active conservation on protected lands. These scenarios are summarized below and in Table 17.

Scenario 1 – Status Quo and Lower Emissions

Under the Status Quo and Lower Emissions scenario, factors that influence relict trillium populations are assumed to remain constant over both time steps. Urbanization is estimated using a greater than 40 to 50 percent probability of urbanization within each population unit. Land use changes are projected to occur in each population unit as modeled under the SRES B2 scenario (similar to RCP 4.5). Habitat threats including non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts are expected to influence population resiliency at the current rate. However, populations on protected lands are expected to have a lower impact to resiliency over time than on non-protected populations.

Scenario 2 – Status Quo and Higher Emissions

Under the Status Quo and Higher Emissions scenario, factors that influence the relict trillium populations are assumed to remain constant over both time steps. Like Scenario 1, urbanization is estimated using a greater than 40 to 50 percent probability of urbanization within each population. However, land use changes are projected to occur in each population as modeled under the SRES A2 scenario (similar to RCP 8.5). Habitat threats including non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts are expected to influence population resiliency at the current rate. However, populations on protected lands are expected to have a lower impact to resiliency over time than on non-protected populations.

Scenario 3 – Increased Impacts and Higher Emissions

Under the Increased Impacts and Higher Emissions scenario, factors that influence relict trillium populations are assumed to increase over both time steps. Urbanization is estimated using a greater than 1 percent probability of urbanization within each population unit (any projected increase in urbanization). Land use changes are projected to occur in each population unit as modeled under the SRES A2 scenario (similar to RCP 8.5). Habitat threats including non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts are expected to increase above the current rate. However, populations on protected lands are expected to have a lower impact to resiliency over time than on non-protected populations.

Scenario 4 – Conservation

Under the Conservation scenario, factors that influence the relict trillium population are the same as modeled in Scenario 2, but habitat threats for populations occurring on protected lands are assumed to be mitigated by conservation management. Urbanization is modeled to reflect a greater than 40 to 50 percent probability of urbanization within each population unit. Land use changes are projected to occur in each population unit as modeled under the SRES A2 scenario (similar to RCP 8.5). Habitat threats including non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts are expected to influence population resiliency at the current rate. However, populations on protected lands are assumed to be actively managed for the benefit of the species, and therefore impacts are assumed to be mitigated. Populations on non-protected lands are projected to experience habitat threats above the current level.

As described in sections 5.2.1, 5.2.2, and 5.2.3 above, for each scenario we used the SLEUTH model to forecast impacts from urbanization, the FORE-SCE model to forecast impacts from climate-influenced land use change, and land protection status to forecast the influence habitat threats. Then, for each of the habitat influences we constructed resiliency adjustment score rule sets to determine the change in resiliency of relict trillium populations from the current to future conditions under each scenario and at two time steps, year 2040 and 2080 (Table 18).

Table 17. Summary of relict trillium future scenarios.

Scenarios	**Scenario 1: Status Quo – Lower Emissions**	**Scenario 2: Status Quo – Higher Emissions**	**Scenario 3: Increased impacts – Higher Emissions**	**Scenario 4: Conservation Status Quo – Higher Emissions – Managed Lands**
Urbanization (SLEUTH)	>40-50% probability of urbanization within population unit	>40-50% probability of urbanization within population unit	>1% probability of urbanization within population unit	>40-50% probability of urbanization within population unit
Land use/Land cover change (FORE-SCE)	Percent of suitable habitat loss/gain under SRES B2 (RCP 4.5)	Percent of suitable habitat loss/gain under SRES A2 (RCP 8.5)	Percent of suitable habitat loss/gain under SRES A2 (RCP 8.5)	Percent of suitable habitat loss/gain under SRES A2 (RCP 8.5)
Habitat Threats	Habitat threats continue at current level	Habitat threats continue at current level	Habitat threats increase in magnitude	Habitat threats managed on protected lands

Table 18. Summary of future condition resiliency adjustment scores. Influences for each time step include Urbanization (percent increase from SLEUTH), Land Use Change (percent loss in suitable habitat from FORE-SCE), and Habitat Threats.

Influence	**Time Step**	**Adjustment Scale**	**Adjustment Score**
Urbanization	2040/2080	40-100% increase	-0.8
Urbanization	2040/2080	11-39% increase	-0.6
Urbanization	2040/2080	6-10% increase	-0.4
Urbanization	2040/2080	0.1-5% increase	-0.2
Urbanization	2040/2080	0% increase	0
Land Use Change	2040/2080	40-100% loss	-0.8
Land Use Change	2040/2080	11-39% loss	-0.6
Land Use Change	2040/2080	6-10% loss	-0.4
Land Use Change	2040/2080	0.1-5% loss	-0.2
Land Use Change	2040/2080	0% gain or no loss	0

Habitat Threats	2040/2080 Scenario 4	protected	0
Habitat Threats	2040/2080 Scenario 1 - 3	protected	-0.2
Habitat Threats	2040 Scenario 1, 2, & 4	non-protected	-0.4
Habitat Threats	2040 Scenario 3	non-protected	-0.6
Habitat Threats	2080 Scenario 1, 2, & 4	non-protected	-0.6
Habitat Threats	2080 Scenario 3	non-protected	-0.8

Next, for each scenario and time step we calculated an overall future resiliency score for each population by summing the current condition resiliency score and future resiliency adjustment scores for each habitat influence in each future scenario. An example overall future resiliency score calculation for population 22 is shown in Table 19. Finally, populations were assigned an overall future resiliency condition class using the scale in

Table 20.

Table 19. Example of overall future resiliency score calculation for relict trillium population 22 (non-protected) using future condition of habitat factors and scenarios described in Table 17 and Table 18).
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Current Condition Resiliency Class and Score	**Scenario**	**Resiliency Adjustment-Urbanization**	**Resiliency Adjustment-Climate-influenced Land Use Change**	**Resiliency Adjustment-Habitat Threats***	**Overall Future Resiliency score**
3.29	2040 Scenario 1	-0.2	-0.2	-0.4	2.49
3.29	2040 Scenario 2	-0.2	-0.4	-0.4	2.29
3.29	2040 Scenario 3	-0.2	-0.2	-0.6	2.29
3.29	2040 Scenario 4	-0.2	-0.2	-0.4	2.49
3.29	2080 Scenario 1	-0.4	-0.4	-0.6	1.89
3.29	2080 Scenario 2	-0.4	-0.8	-0.6	1.49
3.29	2080 Scenario 3	-0.6	-0.8	-0.8	1.09
3.29	2080 Scenario 4	-0.6	-0.8	-0.6	1.49

Table 20. Scale used to determine overall future resiliency condition class for relict trillium populations. Overall scores were calculated by summing the current condition resiliency score and future resiliency adjustment scores for each habitat influence. See Table 19 for example.

Overall Resiliency Condition Class	Extirpated	Very Low	Low	Moderate	High
Overall Resiliency Score	≤0	>0 to <1.75	1.75 to <2.50	2.50 to <3.25	≥3.25

5.3 Future Condition Results

Predicted habitat changes across the populations suggests a fairly steady linear pattern over time. Under the FORE-SCE low emissions projection, overall habitat changes were -0.87 percent in 2040 and +1.21 percent in 2080, where a negative percent change indicates a loss of habitat and positive percent change indicates an increase. Under the high emissions projection, habitat changes were -6.97 percent in 2040 and were -30.22 percent in 2080. Fourteen populations (31 percent) were predicted to be negatively affected by land use change through the loss of 2.11 to 3,339.81 acres of suitable habitat. Whereas this pattern of steady habitat loss over time appeared to hold for relict trillium populations, the magnitude of habitat loss was much more variable at these smaller spatial scales. As stated previously, a modeled loss of all habitat within a given population should not be construed as an actual loss of the population but rather an indication of the level of potential future impact.

For the six Representation Units, habitat change by 2040 ranged from -10.20 percent to 16.74 percent under the low emissions projection and -41.36 percent to 8.52 percent under the high emissions projection. Total habitat change by 2080 ranged from -14.94 percent to 8.47 percent under the low emissions projection and -100 percent to -4.66 percent under the high emissions projection (Table 21). For the 44 relict trillium populations evaluated, total predicted habitat change by 2040 ranged from -0.87 percent under the low emissions projection to -6.97 percent under the high emissions projection. Total habitat change by 2080 ranged from 1.21 percent under the low emissions projection to -30.22 percent under the high emissions projection.

Table 21. Loss of habitat (mixed and deciduous forest land cover types) for relict trillium populations by Representation Unit for Low (B2) and High (A2) Emissions projections from the FORE-SCE model.

Scenario	**High Emissions (A2)**	**High Emissions (A2)**	**Low Emissions (B2)**	**Low Emissions (B2)**
Representation Unit (RU)	**2040**	**2080**	**2040**	**2080**
ALT	-0.35	-17.79	4.78	6.01
APE	-5.91	-29.03	-2.87	2.22
APW	8.52	-4.66	-2.72	8.47
CHO	-2.56	-18.29	16.74	-14.32
SVE	-41.36	-86.61	-10.20	-14.94
SVW	-30.10	-100.00	0.00	-0.52

5.3.1 Future Resiliency

We predicted the future resiliency of relict trillium populations using the methods and scenarios described above. Future predictions were estimated at two time steps (2040 and 2080) and the scenarios take into account a range of impacts from future urbanization, climate-influenced land use change, and habitat threats (i.e., non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts). The current resiliency and predicted future resiliency for each population is shown for each of the four future scenarios in Table 22 and Appendix F for 2040 and Table 23, and Appendix G for 2080. In general, impacts to relict trillium increase across scenarios and time steps from Scenario 1 to 3, respectively. The Conservation Scenario (Scenario 4) shows some maintenance of population resiliency compared to Scenarios 1 to 3. In 2040, there is a decrease from current condition in the number of populations characterized as having high resiliency (from ten populations to two populations under Scenarios 1 and 2, one under Scenario 3, and four under Scenario 4). There is a slight increase in the number of populations (22) characterized as low in Scenario 1 and fewer (16, 15 and 15, respectively) in Scenarios 2 through 4. However, the number of populations with very low resiliency increases from current condition (2) in all scenarios (11 in Scenario 1 and 14 in Scenarios 2 through 4) (Table 22). Three populations are predicted to be extirpated in Scenarios 1, 2, and 4, and five populations are predicted to be extirpated in Scenario 3. By 2080, zero to two populations are predicted to have high resiliency and four to nine populations have moderate resiliency (**Error! Reference source not found.**Table 23). Two populations are predicted to be extirpated in Scenarios 1, 2, and 4, and five populations are predicted to be extirpated in Scenario 3. The following is a summary of future population resiliency for each scenario and timestep.

Table 22. Future resiliency for relict trillium (number of estimated populations in each resiliency category) in 2040 under four future scenarios.

Scenarios	**Current**	**Scenario 1 Status Quo – Lower Emissions**	**Scenario 2 Status Quo – Higher Emissions**	**Scenario 3 Increased Impacts – Higher Emissions**	**Scenario 4 Status Quo – Higher Emissions with Conservation**
High Resiliency	10	2	2	1	4
Moderate Resiliency	12	6	10	9	9
Low Resiliency	20	22	15	15	14
Very Low Resiliency	2	11	14	14	14
Extirpated	0	3	3	5	3
Total	44	44	44	44	44

Table 23. Future resiliency for relict trillium (number of estimated populations in each resiliency category) in 2080 under four future scenarios.

Scenarios	**Current**	**Scenario 1 Status Quo – Lower Emissions**	**Scenario 2 Status Quo – Higher Emissions**	**Scenario 3 Increased Impacts – Higher Emissions**	**Scenario 4 Status Quo – Higher Emissions with Conservation**
High Resiliency	10	0	1	1	2
Moderate Resiliency	12	9	6	4	6
Low Resiliency	20	19	18	16	18
Very Low Resiliency	2	14	17	18	16
Extirpated	0	2	2	5	2
Total	44	44	44	44	44

Scenario 1 – Status Quo and Lower Emissions

Under Scenario 1, future urbanization and impacts from habitat threats are expected to continue at current rates. Future land use change is forecasted under the lower emissions climate projection. The effects of this scenario on relict trillium population resiliency increase from 2040 to 2080. In this scenario, resiliency changes from 10 high and 12 moderate resiliency populations (49 percent) in current condition, to 2 and 6 (18 percent) in 2040 and 0 high and 9 moderate resiliency populations (20 percent) in 2080. The number of low resiliency populations slightly increases in this scenario from 20 populations (45 percent) to 22 populations (49 percent) in 2040 and decreases to 19 populations (42 percent) in 2080; however, the number of very low resiliency populations increases from 2 populations (4 percent) to 11 populations (34 percent) in 2040 and 14 populations (32 percent) in 2080. Most populations in 2040 and 2080 (33 populations, 75 percent) are in low to very low resiliency. In 2040, three populations (7 percent) become extirpated, and two populations (5 percent) become extirpated in 2080 under this scenario.

Scenario 2 – Status Quo and Higher Emissions

Scenario 2 is similar to Scenario 1 with urbanization and impacts from habitat threats expected to continue at current rates. However, future land use change is forecasted under the higher emissions climate projection. The negative effects of this scenario on relict trillium population resiliency also increase from 2040 to 2080. In this scenario, resiliency changes from 10 high and 12 moderate resiliency populations (49 percent) in current condition, to 2 and 9 (24 percent) in 2040 and 1 high and 6 moderate resiliency populations (16 percent) in 2080. The number of low resiliency populations decreases in this scenario from 20 populations (45 percent) to 16 populations (36 percent) in 2040 and 18 populations (40 percent) in 2080; however, the number of very low resiliency populations increases to 14 populations (32 percent) in 2040 and 17 populations (39 percent) in 2080. Most populations (2040: 33 populations, 75 percent; 2080: 35 populations, 80 percent) are in low to very low resiliency. In 2040, three populations (7 percent) become extirpated, and two populations (5 percent) become extirpated in 2080 under this scenario.

Scenario 3 – Increased Impacts and Higher Emissions

Under Scenario 3, future land use change is forecasted under the higher emissions climate projection like Scenario 2, however urbanization (all probabilities) and habitat threats increase above current rates. The negative effects of this scenario on relict trillium population resiliency also increase from 2040 to 2080. In this scenario, resiliency changes from 10 high and 12 moderate resiliency populations (49 percent) in current condition, to 1 and 9 (22 percent) in 2040 and 1 high and 4 moderate resiliency populations (11 percent) in 2080. The number of low resiliency populations decreases in this scenario from 20 populations (45 percent) to 15 populations (33 percent) in 2040 and 16 populations (36 percent) in 2080; however, the number of very low resiliency populations increases to 14 populations (32 percent) in 2040 and 18 populations (41 percent) in 2080. Most populations (2040: 29 populations, 66 percent; 2080: 34

populations, 77 percent) are in low to very low resiliency. In 2040, five populations (11 percent) become extirpated in 2040 and 2080 under this scenario.

Scenario 4 – Conservation

Scenario 4 is similar to Scenario 2 with urbanization and impacts from habitat threats expected to continue at current rates and future land use change is forecasted under the higher emissions climate projection. However, protected areas are assumed to be actively managed for the benefit of the species. The negative effects of this scenario on relict trillium population resiliency also increase from 2040 to 2080, however some population resiliency is conserved compared to Scenario 1 to 3. In this scenario, resiliency changes from 10 high and 12 moderate resiliency populations (49 percent) in current condition, to 4 and 8 (27 percent) in 2040 and 1 high and 4 moderate resiliency populations (11 percent) in 2080. The number of low resiliency populations decreases in this scenario from 20 populations (45 percent) to 15 populations (33 percent) in 2040 and 16 populations (36 percent) in 2080; however, the number of very low resiliency populations increases to 14 populations (32 percent) in 2040 and 16 populations (36 percent) in 2080. Most populations (2040: 34 populations, 76 percent; 2080: 40 populations, 89 percent) are in low to very low resiliency. In 2040, three populations (7 percent) become extirpated, and two populations (5 percent) become extirpated in 2080 under this scenario.

5.3.2 Future Representation

Representation reflects a species' adaptive capacity to respond to changing environmental conditions over time. To predict species' representation under plausible future scenarios, we characterized the number and distribution of relict trillium populations in the six RUs under the four future scenarios described in section 5.2, Methods and Scenarios. Although population resiliency is predicted to generally decline, future representation is predicted to remain steady for relict trillium across all RUs in each scenario and time step (Table 24). Extirpated populations are predicted to occur in some RUs across most future scenarios and time steps. In the ALT RU, one population is extirpated in all scenarios except for Scenario 3 in 2080 where two are extirpated. In the APE RU, one population is extirpated in all scenarios except for Scenario 3 in 2080 where two are extirpated and Scenarios 1, 2, and 4 in 2080 where no populations are extirpated. In the APW RU, one population is extirpated in all scenarios. No populations in the CHO, SVW, and SVE RUs are extirpated, except for 2080 Scenario 3 in the CHO and 2040 Scenario 3 in the SVE RUs where one population is extirpated.

In the SVW and SVE RUs, there are no high to moderate resiliency populations in any future scenario. Only one population is currently extant in the SVW RU, which declines from high to low resiliency in Scenario 1 in 2040 and all scenarios in 2080, and to very low resiliency in Scenario 2 to 4 in 2040. In Scenarios 1, 2, and 4 in 2040 and Scenarios 1, 2, and 3 in 2080, the SVE RU has two very low resiliency populations, and one low and very low population in Scenario 4 in 2080. There is one very low and one extirpated population in 2040 Scenario 3, and one low and one very low population in 2080 Scenario 4. All other RUs maintain at least one high or moderate resiliency population thru all scenarios and time steps. The following is a summary of future species representation for each scenario and timestep.

Table 24. Predicted relict trillium population resiliency (estimated number of populations by category) for the six RUs under four scenarios at 2040 and 2080. Scenario 1 is status quo – lower emissions; Scenario 2 is status quo – higher emissions, Scenario 3 is increased impacts and higher emissions, and Scenario 4 is Conservation. Resiliency is reported by resiliency condition category (high, moderate, low, very low, or extirpated).

RU - ALT	**High**	**Moderate**	**Low**	**Very Low**	**Extirpated**	**Total Evaluated Extant Populations**
Current Resiliency	4	1	3	0	0	8
Scenario 1 - 2040	0	2	4	1	1	7
Scenario 2 – 2040	0	3	3	1	1	7
Scenario 3 – 2040	0	3	3	1	1	7
Scenario 4 – 2040	1	2	3	1	1	7
Scenario 1 – 2080	0	2	4	1	1	7
Scenario 2 – 2080	0	1	4	2	1	7
Scenario 3 - 2080	0	1	4	1	2	6
Scenario 4 - 2080	1	0	4	2	1	7

RU - APE	**High**	**Moderate**	**Low**	**Very Low**	**Extirpated**	**Total Evaluated Extant Populations**
Current Resiliency	4	5	12	1	0	22
Scenario 1 - 2040	1	2	11	7	1	21
Scenario 2 - 2040	1	4	10	6	1	21
Scenario 3 - 2040	1	3	9	7	2	20
Scenario 4 - 2040	2	4	9	6	1	21
Scenario 1 - 2080	0	4	10	8	0	22
Scenario 2 - 2080	1	2	10	9	0	22
Scenario 3 - 2080	1	2	7	11	1	21
Scenario 4 - 2080	1	3	9	9	0	22

RU - APW	**High**	**Moderate**	**Low**	**Very Low**	**Extirpated**	**Total Evaluated Extant Populations**
Current Resiliency	1	1	2	1	0	5
Scenario 1 - 2040	1	0	2	1	1	4
Scenario 2 - 2040	1	0	2	1	1	4
Scenario 3 - 2040	0	1	2	1	1	4
Scenario 4 - 2040	1	0	2	1	1	4
Scenario 1 - 2080	0	1	2	1	1	4
Scenario 2 - 2080	0	1	1	2	1	4
Scenario 3 - 2080	0	1	1	2	1	4
Scenario 4 - 2080	0	1	1	2	1	4

RU - CHO	High	Moderate	Low	Very Low	Extirpated	Total Evaluated Extant Populations
Current Resiliency	0	3	3	0	0	6
Scenario 1 - 2040	0	2	4	0	0	6
Scenario 2 - 2040	0	3	0	3	0	6
Scenario 3 - 2040	0	2	1	3	0	6
Scenario 4 - 2040	0	3	0	3	0	6
Scenario 1 - 2080	0	2	2	2	0	6
Scenario 2 - 2080	0	2	2	2	0	6
Scenario 3 - 2080	0	0	3	2	1	5
Scenario 4 - 2080	0	2	2	2	0	6
RU - SVE	**High**	**Moderate**	**Low**	**Very Low**	**Extirpated**	**Total Evaluated Extant Populations**
Current Resiliency	0	2	0	0	0	2
Scenario 1 - 2040	0	0	0	2	0	2
Scenario 2 - 2040	0	0	0	2	0	2
Scenario 3 - 2040	0	0	0	1	1	1
Scenario 4 - 2040	0	0	0	2	0	2
Scenario 1 - 2080	0	0	0	2	0	2
Scenario 2 - 2080	0	0	0	2	0	2
Scenario 3 - 2080	0	0	0	2	0	2
Scenario 4 - 2080	0	0	1	1	0	2
RU - SVW	**High**	**Moderate**	**Low**	**Very Low**	**Extirpated**	**Total Evaluated Extant Populations**
Current Resiliency	1	0	0	0	0	1
Scenario 1 - 2040	0	0	1	0	0	1
Scenario 2 - 2040	0	0	0	1	0	1
Scenario 3 - 2040	0	0	0	1	0	1
Scenario 4 - 2040	0	0	0	1	0	1
Scenario 1 - 2080	0	0	1	0	0	1
Scenario 2 - 2080	0	0	1	0	0	1
Scenario 3 - 2080	0	0	1	0	0	1
Scenario 4 - 2080	0	0	1	0	0	1

Scenario 1 – Status Quo and Lower Emissions

Under Scenario 1, relict trillium is represented in all six RUs in 2040 and 2080 (Figure 18, Table 24). However, two to three populations have been extirpated and eight and nine have high or moderate resiliency populations across the RUs in 2040 and 2080, respectively. The APE RU has the most extant current populations (22) with four high and five moderate resiliency populations currently. However, population resiliency decreases to one high and two moderate resiliency populations in 2040 and continues decreasing to zero high and four moderate in 2080. The ALT RU has seven extant populations in both 2040 and 2080. The four high and 1 moderate current populations are estimated to decrease to zero high and two moderate resiliency populations in both 2040 and 2080. The number of very low resiliency populations increases to one and one is extirpated in 2040 and 2080. The APW RU has four extant and one extirpated population in 2040 and 2080. There is one high resiliency and three low or very low resiliency populations in 2040 and one moderate and three low or very low resiliency populations in 2080. The CHO RU has six extant populations in 2040 and 2080. There are two and four moderate and low resiliency populations remaining in 2040. In 2080, there are two moderate, low, and very low resiliency populations across all scenarios. Two populations remain extant in the SVE RU but their resiliency decreases from moderate to very low. Similarly, the one extant population in the SVW RU remains in 2040 and 2080; however, the resiliency decreases from high to low in 2040 and 2080.

Scenario 2 – Status Quo and Higher Emissions

Under Scenario 2, relict trillium remains represented in all six RUs in 2040 and 2080 (Figure 19, Table 24). However, two to three populations have been extirpated and 11 and 7 have high or moderate resiliency populations across the RUs in 2040 and 2080, respectively. The APE RU has the most extant populations (21) with one high and two or three moderate resiliency in 2040, and one high and two moderate resiliency populations in 2080. The ALT RU decreases from eight to seven extant populations in both 2040 and 2080. There are three moderate resiliency populations in 2040 and one in 2080. The number of very low resiliency populations increases to one in 2040 and two in 2080, and one population is extirpated in both time steps. The APW RU has four extant and populations in 2040 and 2080. There is one high or moderate resiliency and three low or very low resiliency populations in 2040, and one moderate resiliency and three low or very low resiliency populations in 2080. One population is extirpated in both time steps. The CHO RU has six extant populations in 2040 and 2080. There are three moderate and three very low resiliency populations remaining in 2040. In 2080, there are four low or very low resiliency populations and two moderate resiliency populations. The two extant populations in the SVE RU remain in 2040 and 2080; however, their resiliency decreases from moderate to very low in 2040 and 2080. Similarly, the one extant population in the SVW RU remains in 2040 and 2080; however, the resiliency decreases from high to very low in 2040 and to low in 2080.

Scenario 3 – Increased Impacts and Higher Emissions

Under Scenario 3, relict trillium is represented in all six RUs in 2040 and 2080 (Figure 20, Table 24). However, five populations have been extirpated and ten and five have high or moderate resiliency populations across the RUs in 2040 and 2080, respectively. The APE RU has the most extant populations (20 to 21) with one high and three moderate resiliency populations in 2040, decreasing to one high and two moderate in 2080. The ALT RU has seven extant populations in both 2040 and six extant populations in 2080. There are three high or moderate resiliency populations in 2040 and only one moderate resiliency population in 2080. The number of very low resiliency populations increases to one in 2040 and 2080. The APW RU has four extant and populations in 2040 and 2080. There is one moderate resiliency, three low or very low resiliency, and one extirpated population in 2040 and 2080. The CHO RU has six extant populations in 2040 and five in 2080. There are two moderate and three very low resiliency populations remaining in 2040. In 2080, there are no high or moderate, three low and two very low resiliency populations, and one extirpated population. Of the two currently extant populations in the SVE RU, one is extirpated, and one remains in 2040 and both remain in 2080; however, the resiliency of the remaining populations decreases to very low in both time steps. Similarly, the one extant population in the SVW RU remains in 2040 and 2080; however, the resiliency decreases from high to very low in 2040 and to low resiliency in 2080.

Scenario 4 – Conservation

Under Scenario 4, relict trillium remains represented in all six RUs in 2040 and 2080 (Figure 21, Table 24). Three and 2 populations have been extirpated and 12 and 8 have high or moderate resiliency populations across the RUs in 2040 and 2080, respectively. The APE RU has the most extant populations (21 to 22) with two high and three moderate resiliency populations in 2040, decreasing to one high and three moderate in 2080. The ALT RU has seven extant populations in both 2040 and 2080. There is one high and two moderate resiliency populations in 2040 and one high resiliency population in 2080. The number of very low resiliency populations increases to one in 2040 and 2 in 2080. The APW RU has four extant and populations and one extirpated population in 2040 and 2080. There is one high or moderate resiliency and three low or very low resiliency populations in 2040 and 2080. The CHO RU has six extant populations in 2040 and 2080. There are three moderate, and three very low resiliency populations remaining in 2040. In 2080, there are two low resiliency, two very low populations, and two moderate resiliency populations. The two extant populations in the SVE RU remain in 2040 and 2080; however, their resiliency decreases to very low in 2040 and to one low and one very low in 2080. Similarly, the one extant population in the SVW RU remains in 2040 and 2080; however, the resiliency decreases from high to very low in 2040 and to low in 2080.

5.3.3 Future Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. Redundancy for the relict trillium is characterized by having multiple resilient (high or moderate) and representative populations distributed across the species' range. Redundancy for relict trillium decreases from current condition with each scenario and time step. Three of the six RUs, the APW, SVE, and SVW RUs, have no redundancy of resilient populations in any future scenario. The APW RU only has one high or moderate population in any scenario and the SVE and SVW RUs have no resilient populations in any future scenario. One additional RU (CHO) also loses redundancy under one scenario (Scenario 3) in 2080 (Table 24). Redundancy in the ALT and

APW RUs is reduced in all scenarios and time steps. At least one population is extirpated in nearly all but four scenarios and time steps for the ALT, APE, and APW RUs. In the CHO RU, redundancy remains steady in Scenarios 2 and 4 in 2040, and decreases in all other scenarios and time steps, except under Scenario 3 in 2080 as mentioned above.

Range wide, redundancy decreases from 22 resilient (high and moderate resiliency) populations in current condition. In 2040, resilient populations decrease to 8, 11, 10, and 12 for Scenarios 1, 2, 3, and 4, respectively and in 2080 to 9, 7, 5 and 8 for Scenarios 1, 2, 3, and 4, respectively (Table 24). Therefore, based on this assessment the species is predicted to maintain redundancy (but at lower levels) range wide in the future.

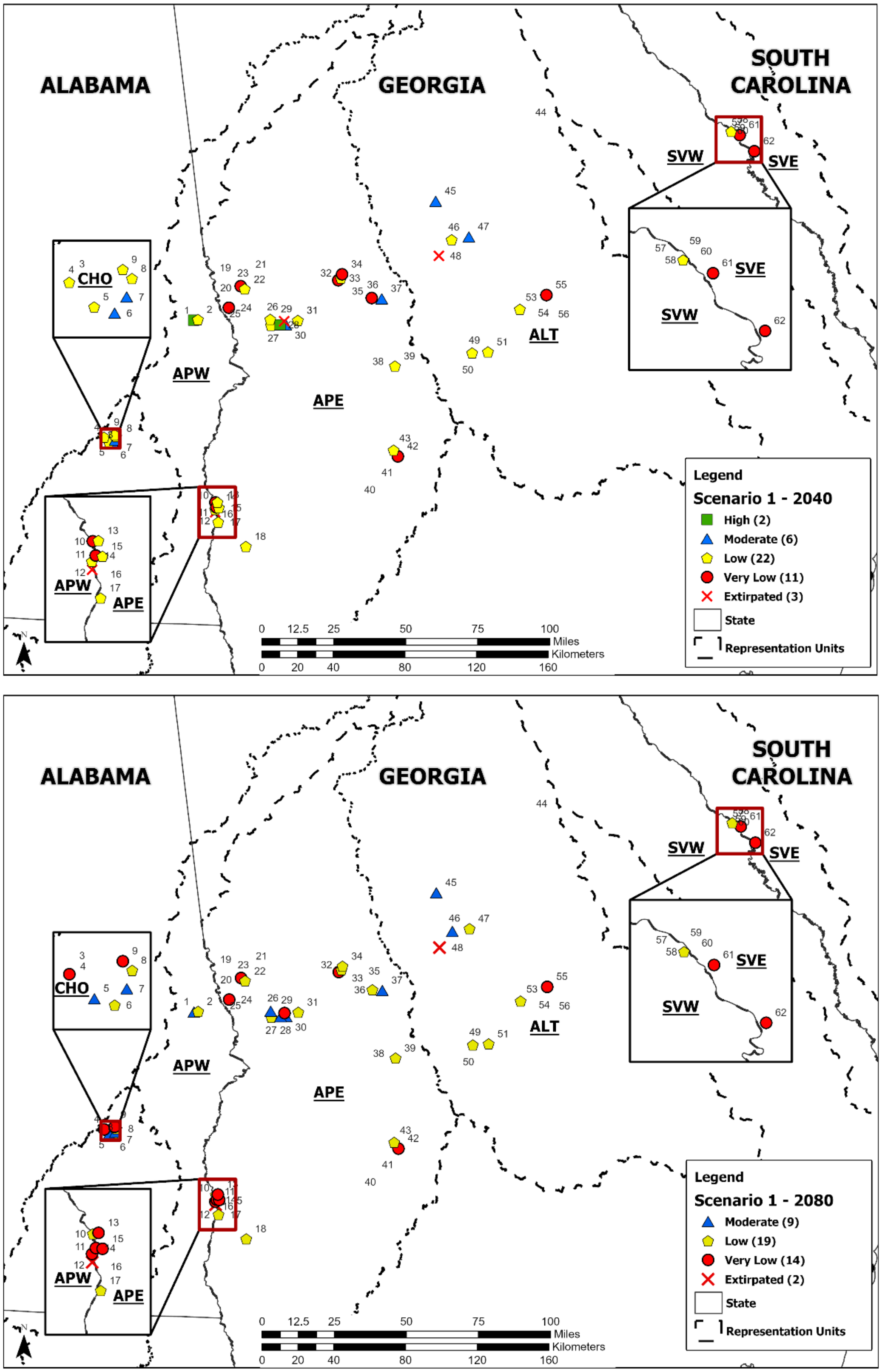

Figure 18. Relict trillium population resiliency across Representation Units for Scenario 1 (Status Quo – Lower Emissions) at two time steps, 2040 and 2080.

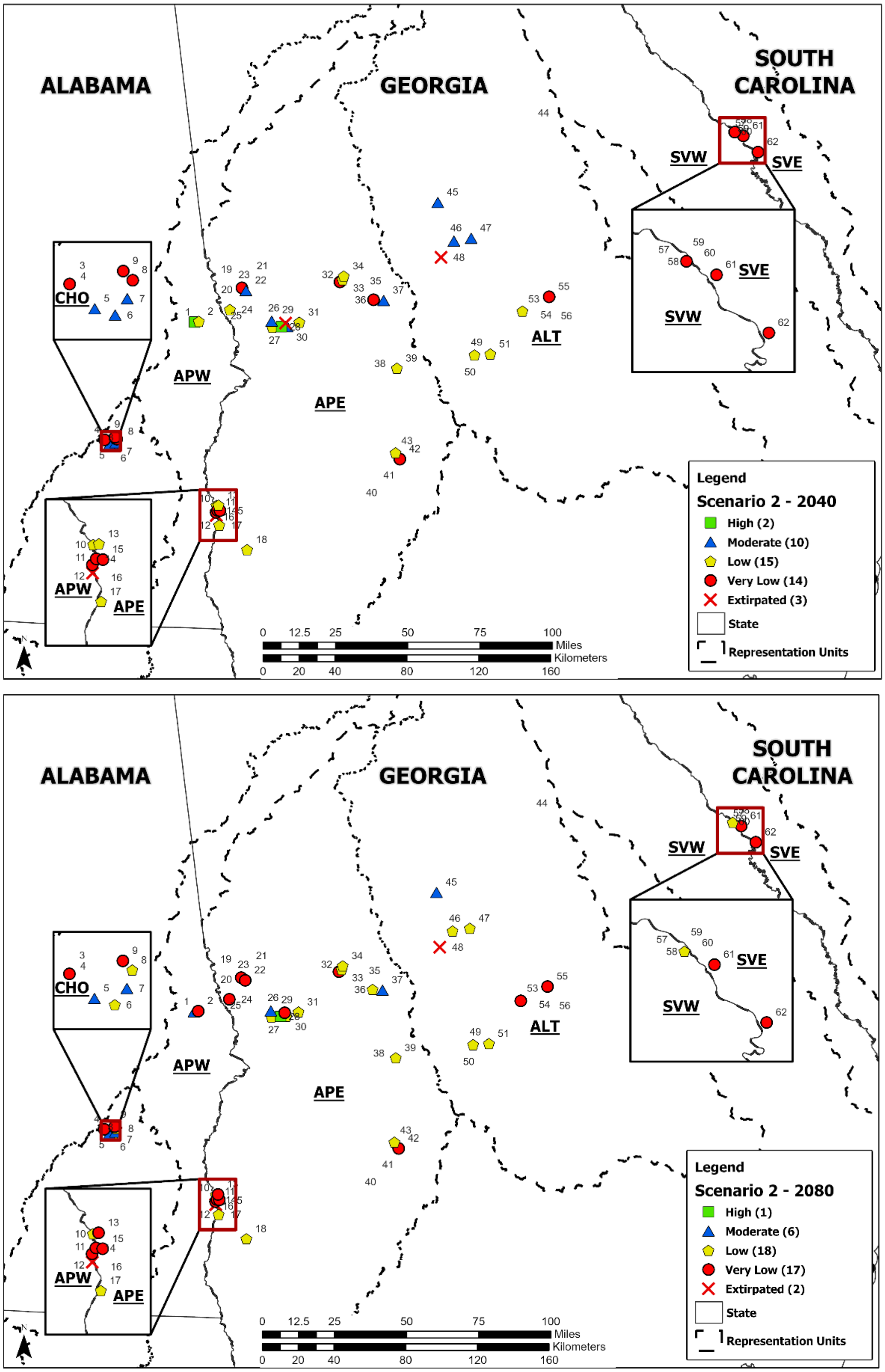

Figure 19. Relict trillium population resiliency across Representation Units for Scenario 2 (Status Quo –Higher Emissions) at two time steps, 2040 and 2080.

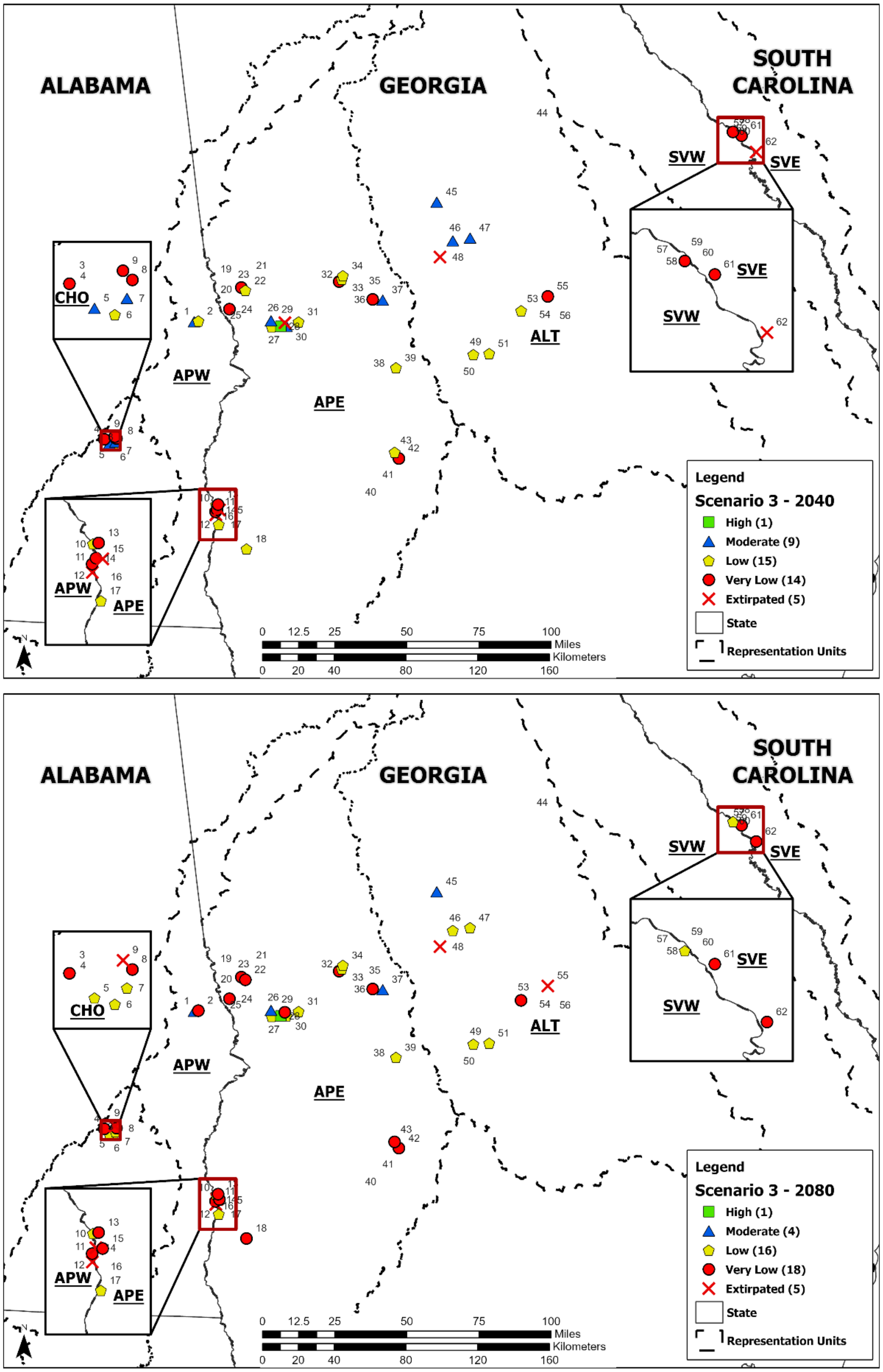

Figure 20. Relict trillium population resiliency across Representation Units for Scenario 3 (Increased Impacts – Higher Emissions) at two time steps, 2040 and 2080.

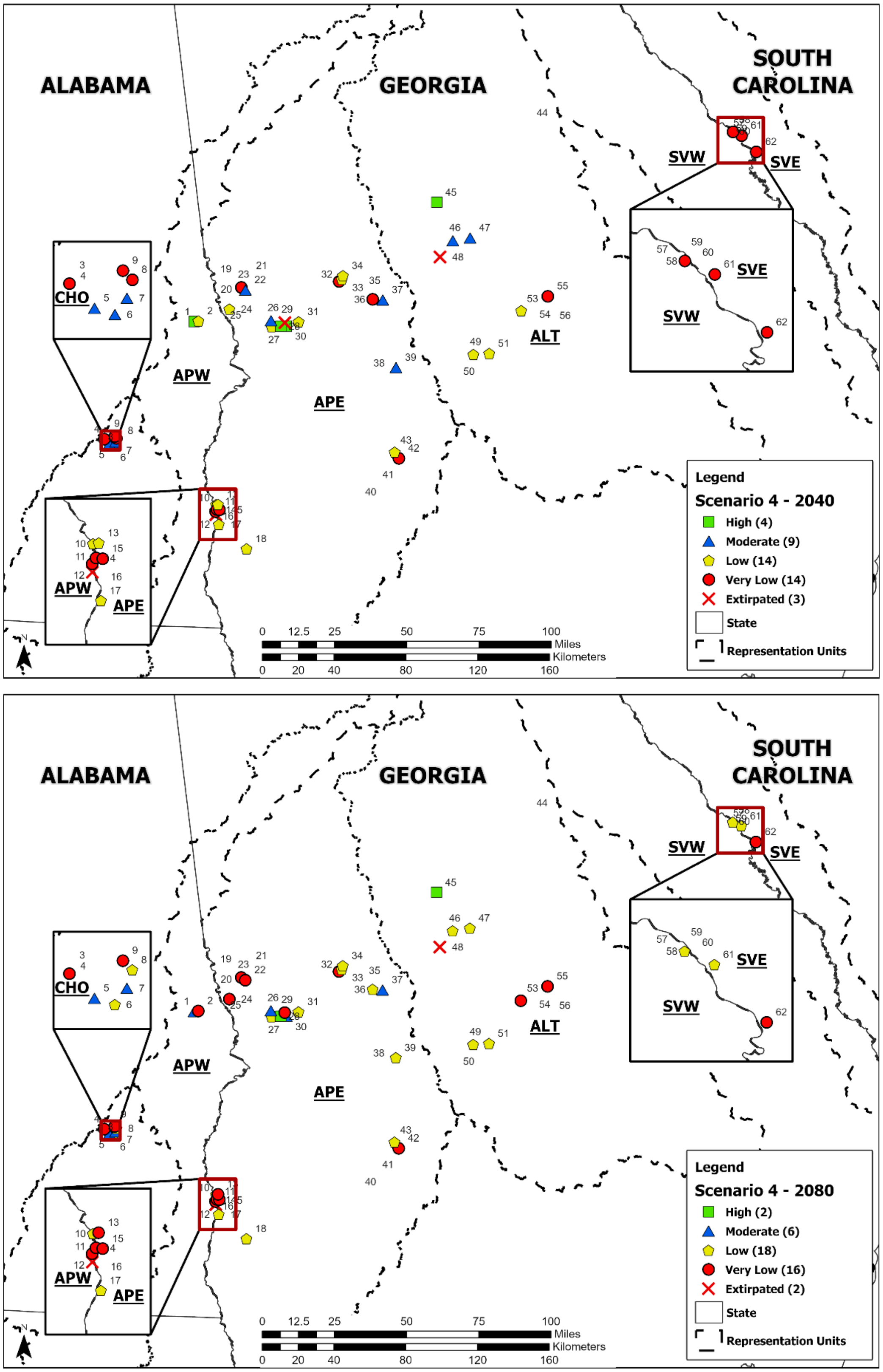

Figure 21. Relict trillium population resiliency across Representation Units for Scenario 4 (Conservation) at two time steps 2040 and 2080.

5.4 Summary of Future Conditions and Viability

We predicted the future resiliency of relict trillium populations at two time steps (2040 and 2080) using four scenarios that take into account a range of impacts from future urbanization, climate-influenced (emissions) land use change, and habitat threats (i.e., non-native invasive plant species, deer browsing, feral hogs, and hydrologic impacts). The scenarios were: (1) Status Quo – Lower Emissions, (2) Status Quo – Higher Emissions, (3) Increase Impacts – Higher Emissions, and (4) Conservation.

In our assessment of the current resiliency of the 44 current populations, 10 (22 percent) have high, 12 (27 percent) have moderate, 21 (47 percent) have low, and 2 (4 percent) have very low population resiliency (Figure 17, Table 12). In the future, impacts to relict trillium population resiliency increase and population resiliency generally decreases across scenarios and time steps from Scenario 1 to 3, with some resiliency conserved in Scenario 4. Of the assessed populations, 18 (40 percent) of the populations were affected by urbanization in one or more scenarios or time steps, with a range of increased percent urbanized acres of 0.2 to 88.8. Fourteen populations (31 percent) were predicted to be negatively affected by land use change through the loss of 0.35 to 100 percent of suitable habitat. Range wide three to five populations are forecasted to be extirpated. Most populations are in the APE RU (20 to 22) followed by the ALT RU (6 to 7), CHO RU (5 to 6), APW RU (4), SVE RU (1 to 2) and SVW RU (1).

In 2040, high to moderate resiliency populations decrease from current condition (22 resilient populations or 49 percent) to 8 (18 percent) in Scenario 1, 11 (24 percent) in Scenario 2, 10 (22 percent) in Scenario 3, and 12 (27 percent) in Scenario 4. In 2080, high to moderate resiliency populations decrease to nine (20 percent) in Scenario 1, seven (16 percent) in Scenario 2, five (11 percent) in Scenario 3, and eight (18 percent) in Scenario 4. Low, very low, and extirpated populations represent 73 to 82 percent of the populations in all 2040 scenarios and 80 to 89 percent of the populations in all 2080 scenarios. The Conservation scenario (Scenario 4) maintains two to four high and six to eight moderate resiliency populations into the future.

Future representation and redundancy for the species was predicted under these scenarios and time steps by assessing the number of relict trillium populations in the six RUs (watersheds) and assessing the number of resilient and representative populations distributed across the range of the species. In the future, all RUs are represented; however, redundancy is predicted to decline for relict trillium across all RUs and the species' geographic range in each scenario and time step due to declines in population resiliency and extirpations. The eastern (South Carolina, SVE RU) and western (Alabama, CHO and APW RUs) extents of the species' range represent the highest genetic diversity but have low to no redundancy of resilient populations in the future. The SVE and SVW RUs have no resilient populations, the CHO RU has only two to three resilient populations, and the APW RU has one resilient population remaining and there is at least two extirpations in all future scenarios. This reduction in representation and redundancy may increase risk to the species by reducing adaptive capacity (low representation in genetically significant RUs) and increase vulnerability to impacts from catastrophic events (low redundancy).

In conclusion, relict trillium populations are predicted to generally decline in resiliency overtime due to habitat-based impacts from urbanization, land use change, and impacts from habitat threats. The resilient populations (high and moderate resiliency) range from 5 to 12 across scenarios and time steps and are in as many as four RUs and as few as three RUs depending on scenario and time step. However, as many as five of the six RUs lack redundancy depending on the scenario and time step. Conservation (management of habitat threats on protected lands) may increase the potential to maintain resilient populations in some RUs and across the range. Therefore, based on the scenarios assessed, relict trillium is expected to have some level of adaptive capacity (representation) and ability to rebound after catastrophic events (redundancy).

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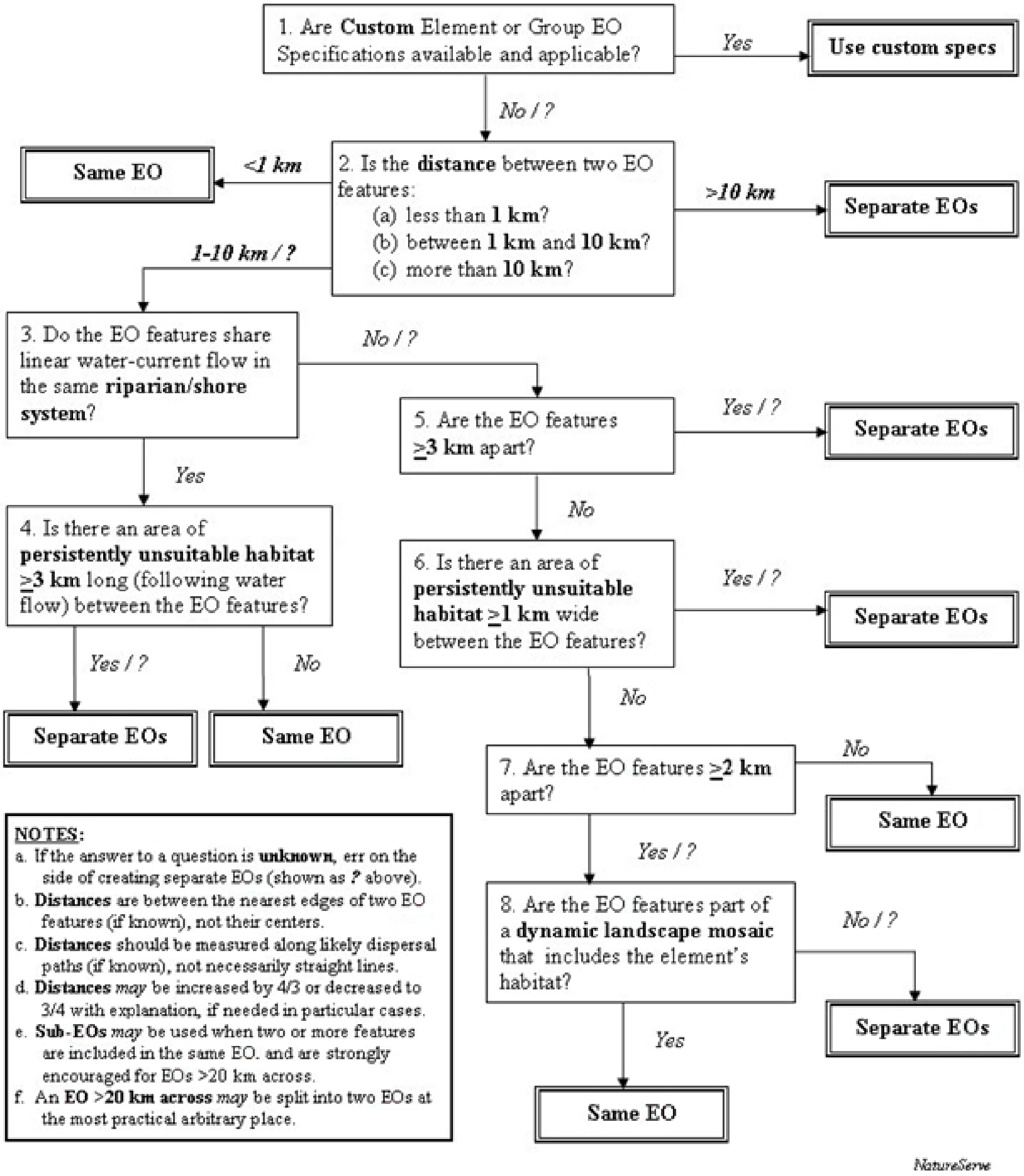
APPENDIX A – ELEMENT OCCURRENCE POPULATION DELINEATION

Habitat-based Plant Element Occurrence Delimitation Guidance, NatureServe, 1 October 2004



NOTES:

a. If the answer to a question is **unknown**, err on the side of creating separate EOs (shown as *?* above).
b. **Distances** are between the nearest edges of two EO features (if known), not their centers.
c. **Distances** should be measured along likely dispersal paths (if known), not necessarily straight lines.
d. **Distances** *may* be increased by 4/3 or decreased to 3/4 with explanation, if needed in particular cases.
e. **Sub-EOs** *may* be used when two or more features are included in the same EO. and are strongly encouraged for EOs >20 km across.
f. An **EO >20 km across** *may* be split into two EOs at the most practical arbitrary place.

APPENDIX B – LIST OF RELICT TRILLIUM POPULATIONS AND ASSOCIATED ELEMENT OCCURRENCES

Population Number	State	EO Number	County	Date of Last Observation	Site Name	Representation Unit (RU)	Level 4 Ecoregion
1	AL	7	Lee	2007-03-24	Little Uchee Creek - Pipeline	Apalachicola West	Southern Outer Piedmont
2	AL	10, 11	Lee	2007-03-20	Little Uchee Creek Upper/Lower Pipeline	Apalachicola West	Southern Outer Piedmont
3	AL	5	Bullock	1990-03-20	Double Creek - Bullock CR45	Choctawhatchee	Southern Hilly Gulf Coastal Plain
4	AL	12	Bullock	2021-04-03	Double Creek - Upper	Choctawhatchee	Southern Hilly Gulf Coastal Plain
5	AL	4	Bullock	2021-03-27	Double Creek - Lower	Choctawhatchee	Southern Hilly Gulf Coastal Plain
6	AL	13	Bullock	2021-04-04	Double Creek - US29	Choctawhatchee	Southern Hilly Gulf Coastal Plain
7	AL	2	Bullock	2011-03-24	Jamback Cemetery	Choctawhatchee	Southern Hilly Gulf Coastal Plain
8	AL	1	Bullock	2021-03-10	Bullock CR8 - Powerline Crossing	Choctawhatchee	Southern Hilly Gulf Coastal Plain
9	AL	3	Bullock	2011-04-26	Bullock CR8 - Bogue Chitta Creek	Choctawhatchee	Southern Hilly Gulf Coastal Plain
10	AL	6	Henry	42021-04-14	Walter F. George Lock & Dam	Apalachicola West	Southeastern Floodplains and Low Terraces
11	AL	8	Henry	2021-04-14	Farmers Landing - North	Apalachicola West	Southern Hilly Gulf Coastal Plain; and Southeastern Floodplains and Low Terraces

Population Number	State	EO Number	County	Date of Last Observation	Site Name	Representation Unit (RU)	Level 4 Ecoregion
12	AL	9	Henry	2021-07-12	Farmers Landing - South	Apalachicola West	Southern Hilly Gulf Coastal Plain; and Southeastern Floodplains and Low Terraces
13	GA	13	Clay	2021-04-06	Town Branch -Lower Cemochechobee/Ft. Gaines	Apalachicola East	Southern Hilly Gulf Coastal Plain; and Southeastern Floodplains and Low Terraces
14	GA	9	Clay	2021-03-22	Lower Ledbetter Br. Ravine	Apalachicola East	Southeastern Floodplains and Low Terraces
15	GA	9	Clay	2021-03-22	Upper Ledbetter Br. Ravine	Apalachicola East	Southeastern Floodplains and Low Terraces
16	GA	10	Clay	1988-05-29	Maidenhair Bluffs North/South	Apalachicola East	Southern Hilly Gulf Coastal Plain; and Southeastern Floodplains and Low Terraces
17	GA	32	Clay	2010-04-15	Kolomoki Creek - Near Mouth	Apalachicola East	Southern Hilly Gulf Coastal Plain; and Southeastern Floodplains and Low Terraces
18	GA	2	Early	2010-04-16	Dry Creek	Apalachicola East	Dougherty Plain
19	GA	61	Harris	2021-03-30	Blanton Creek WMA	Apalachicola East	Southern Outer Piedmont
20	GA	30	Harris	1998-04-22	Joe Hadley Huling Preserve	Apalachicola East	Southern Outer Piedmont

Population Number	State	EO Number	County	Date of Last Observation	Site Name	Representation Unit (RU)	Level 4 Ecoregion
21	GA	60	Harris	2017-03-00	Callaway Gardens/East Farm LLC	Apalachicola East	Southern Outer Piedmont
22	GA	31, 33, 65	Harris	2021-03-30	Little Branch - Tommy Hutcherson/Mulberry Cr/Mt. Moriah/Desportes Prop.	Apalachicola East	Southern Outer Piedmont
23	GA	63	Harris	2021-03-01	Mt. Moriah Baptist Church	Apalachicola East	Sand Hills; and Southern Outer Piedmont
24	GA	59	Muscogee	2018-03-20	Schley Creek	Apalachicola East	Southern Outer Piedmont
25	GA	34	Muscogee	2012-03-04	Standing Boy Creek - SP/Jordan North/South	Apalachicola East	Southern Outer Piedmont
26	GA	26, 39	Muscogee	2020-00-00	Randall Creek North - Ft. Benning/Passmore Property	Apalachicola East	Southern Outer Piedmont
27	GA	18	Muscogee	2020-00-00	Randall Creek South	Apalachicola East	Sand Hills
28	GA	17, 22	Muscogee	2020-00-00	Kendall Creek South/South - Ft. Benning	Apalachicola East	Sand Hills
29	GA	57	Muscogee	2014-04-09	Tar River/Montarella Lake	Apalachicola East	Sand Hills; and Southern Outer Piedmont
30	GA	27, 51	Talbot	2021-03-11	Upatoi Creek - Prevatt North/South, Baker Creek-Ft. Benning	Apalachicola East	Sand Hills
31	GA	64	Talbot	2021-03-11	S. Fork Upatoi Creek - Central of GA RR	Apalachicola East	Sand Hills

Population Number	State	EO Number	County	Date of Last Observation	Site Name	Representation Unit (RU)	Level 4 Ecoregion
32	GA	6	Talbot	2021-04-02	Flint River Plantation - SW	Apalachicola East	Southern Outer Piedmont
33	GA	6	Talbot	2021-04-02	Flint River Plantation	Apalachicola East	Southern Outer Piedmont
34	GA	29	Upson	2021-03-23	Big Lazer WMA/Potato Creek	Apalachicola East	Southern Outer Piedmont
35	GA	21	Upson	2000-04-01	Flint River - Wilson Woods	Apalachicola East	Southern Outer Piedmont
36	GA	49	Taylor	2004-07-22	Lovell Tract	Apalachicola East	Southern Outer Piedmont
37	GA	52	Taylor	2010-04-27	Flint River - Mincey Tract	Apalachicola East	Sand Hills; and Southern Outer Piedmont
38	GA	40	Macon	2000-04-12	Buck Creek Bluffs	Apalachicola East	Coastal Plain Red Uplands
39	GA	14	Macon	2021-03-25	Montezuma Bluffs - North/South	Apalachicola East	Coastal Plain Red Uplands; and Southeastern Floodplains and Low Terraces
40	GA	5	Lee	1939-04-05	Old Byne Plantation	Apalachicola East	Dougherty Plain
41	GA	7	Lee	1989-04-08	Mossy Dell	Apalachicola East	Dougherty Plain
42	GA	55	Lee	2021-04-28	Chokee Creek Cave	Apalachicola East	Dougherty Plain
43	GA	46	Lee	2003-03-07	Chokee Creek	Apalachicola East	Dougherty Plain
44	GA	67	Greene	2021-12-01	Town Creek	Altamaha	Southern Inner Piedmont
45	GA	45, 47, 48	Jasper	2021-04-29	Oconee NF/Beech Ravines 1 and 2	Altamaha	Southern Outer Piedmont

Population Number	State	EO Number	County	Date of Last Observation	Site Name	Representation Unit (RU)	Level 4 Ecoregion
46	GA	19, 25	Jones	2021-03-13	Buttler Creek - Ocmulgee River/Pratts Creek	Altamaha	Southern Outer Piedmont
47	GA	62	Jones	2021-04-29	Walnut Creek/Legacy Farms	Altamaha	Southern Outer Piedmont
48	GA	16	Bibb	2017-03-02	Colaparchee Creek	Altamaha	Southern Outer Piedmont
49	GA	54	Houston	2016-03-31	Big Indian Creek	Altamaha	Coastal Plain Red Uplands
50	GA	24	Houston	1995-06-00	Big Creek	Altamaha	Coastal Plain Red Uplands
51	GA	23	Bleckley	2021-04-08	Ocmulgee WMA - Stephens Bluff	Altamaha	Coastal Plain Red Uplands; and Southeastern Floodplains and Low Terraces
52*	GA	58*	Twiggs	2016-06-00	GA87/Tarversville	Altamaha	Coastal Plain Red Uplands
53	GA	41	Twiggs	2010-03-22	Turkey Creek - Snows Pond	Altamaha	Coastal Plain Red Uplands
54	GA	43	Wilkinson	2001-03-22	Turkey Creek - Near Allentown	Altamaha	Coastal Plain Red Uplands
55	GA	53	Wilkinson	2008-04-02	Maiden Creek East/West	Altamaha	Coastal Plain Red Uplands
56	GA	42	Laurens	2001-03-22	Turkey Creek - Old Montrose Rd. Bridge	Altamaha	Coastal Plain Red Uplands
57	GA	4	Columbia	2000-03-16	Point Comfort South Ravine	Savannah West	Southern Outer Piedmont
58	GA	1	Columbia	2021-04-15	Old Augusta Canal	Savannah West	Southern Outer Piedmont
59	SC	99998, 99999	Edgefield	2021-03-26	Stevens Creek at Savannah River	Savannah East	Southern Outer Piedmont
60	SC	39825	Edgefield	Unknown	McKie Farms	Savannah East	Southern Outer Piedmont

Population Number	State	EO Number	County	Date of Last Observation	Site Name	Representation Unit (RU)	Level 4 Ecoregion
61	SC	15469, 15470, 37089, 37090, 37091, 37092, 37093, 37094, 37095, 37096, 37097, 39800, 39807, 39808, 39809, 39810, 39811, 39813, 39814, 39815, 39816, 39817, 39818, 39820, 39821, 39822, 39824, 39849, 39850, 39851, 39853	Aiken	2021-03-25	North Augusta - Mega Population	Savannah East	Sand Hills; and Southern Outer Piedmont
62	SC	15467	Aiken	2021-03-11	Mason Property	Savannah East	Sand Hills; and Southeastern Floodplains and Low Terraces

* During the SSA peer/partner review process, we were alerted by the Georgia Natural Heritage Program (GNHP) that a relict trillium EO in Georgia was no longer considered valid. A field survey of Georgia EO #58 (Twiggs County) on 3/15/2022 by GNHP botanists determined that the trillium species present at that EO had been mis-identified in prior years as *T. reliquum*. No relict trillium could be found at this EO. Consequently, we have adjusted the number of EOs downward to reflect this new information. For the purposes of this SSA, Georgia has 53 EOs, and the range-wide total of EOs for the species is 102 (Table 4). This EO also represented a stand-alone population, so its removal reduced the number of populations from 62 to 61. However, due to the timing and the need to preserve this information for the administrative record, this EO (GA EO #58 – Twiggs County) is maintained in the Appendices. As shown both above and below, Georgia EO #58 and Population #52 are still numbered in the appendices but were not counted or analyzed for this SSA.

APPENDIX C – CURRENT CONDITION POPULATION RESILIENCY TABLE

Table displays information on each relict trillium population, resiliency scores for demographic and habitat factors (A, R, H, T and current resiliency score), and current resiliency class.

Population #	State	EOs	RU	Date of Last Obs	A	R	H	T	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)
1	AL	7	Apalachicola West	2007-03-24	4.00	4.00	4.00	3.50	3.84	High	No
2	AL	10, 11	Apalachicola West	2007-03-20	2.00	2.50	3.25	3.38	2.75	Moderate	No
3	AL	5	Choctawhatchee	1990-03-20						Historic	No
4	AL	12	Choctawhatchee	2021-04-03	1.00	3.00	2.50	3.25	2.34	Low	No
5	AL	4	Choctawhatchee	2021-03-27	3.00	4.00	2.50	3.50	3.25	Moderate	No
6	AL	13	Choctawhatchee	2021-04-04	4.00	4.00	3.75	1.00	2.97	Moderate	No
7	AL	2	Choctawhatchee	2011-03-24	4.00	1.00	3.25	3.50	3.20	Moderate	No
8	AL	1	Choctawhatchee	2021-03-10	1.00	3.00	2.50	3.50	2.42	Low	No
9	AL	3	Choctawhatchee	2011-04-26	1.00	1.00	3.25	3.50	2.21	Low	No
10	AL	6	Apalachicola West	2021-04-14	3.00	4.00	2.25	1.00	2.38	Low	Yes
11	AL	8	Apalachicola West	2021-04-14	3.00	4.00	1.75	1.00	2.30	Low	No
12	AL	9	Apalachicola West	2021-07-12	1.00	1.00	1.50	1.00	1.09	Very Low	No
13	GA	13	Apalachicola East	2021-04-06	2.00	2.00	4.00	3.25	2.75	Moderate	No
14	GA	9	Apalachicola East	2021-03-22	2.00	2.00	4.00	1.00	2.01	Low	No
15	GA	9	Apalachicola East	2021-03-22	3.00	2.00	4.00	1.00	2.34	Low	No
16	GA	10	Apalachicola East	1988-05-29						Historic	No
17	GA	32	Apalachicola East	2010-04-15	3.00	4.00	2.00	3.25	3.08	Moderate	No
18	GA	2	Apalachicola East	2010-04-16	2.00	2.00	2.25	3.50	2.54	Moderate	No
19	GA	61	Apalachicola East	2021-03-30						Safeguarded	No

Population #	State	EOs	RU	Date of Last Obs	A	R	H	T	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)
20	GA	30	Apalachicola East	1998-04-22						Historic	No
21	GA	60	Apalachicola East	2017-03-00						Safeguarded	No
22	GA	31, 33, 65	Apalachicola East	2021-03-30	4.00	3.00	3.75	2.50	3.29	High	No
23	GA	63	Apalachicola East	2021-03-01	3.00	2.00	2.75	1.00	2.13	Low	No
24	GA	59	Apalachicola East	2018-03-20	1.00	2.00	3.25	3.00	2.21	Low	No
25	GA	34	Apalachicola East	2012-03-04						No Data	Yes
26	GA	26, 39	Apalachicola East	2020-00-00	4.00	4.00	4.00	2.50	3.51	High	Yes
27	GA	18	Apalachicola East	2020-00-00	1.00	4.00	2.25	2.75	2.30	Low	Yes
28	GA	17, 22	Apalachicola East	2020-00-00	4.00	4.00	3.63	3.00	3.61	High	Yes
29	GA	57	Apalachicola East	2014-04-09	1.00	2.00	3.25	2.75	2.13	Low	No
30	GA	27, 51	Apalachicola East	2021-03-11	4.00	3.50	3.88	2.13	3.28	High	Yes
31	GA	64	Apalachicola East	2021-03-11	2.00	2.00	3.75	2.25	2.38	Low	Yes
32	GA	6	Apalachicola East	2021-04-02	1.00	2.00	4.00	1.00	1.68	Very Low	Yes
33	GA	6	Apalachicola East	2021-04-02	3.00	2.00	4.00	1.00	2.34	Low	Yes
34	GA	29	Apalachicola East	2021-03-23	3.00	2.00	4.00	1.00	2.34	Low	Yes
35	GA	21	Apalachicola East	2000-04-01						Historic	No
36	GA	49	Apalachicola East	2004-07-22	1.00	2.00	3.25	3.50	2.38	Low	No
37	GA	52	Apalachicola East	2010-04-27	4.00	4.00	3.25	1.00	2.88	Moderate	Yes
38	GA	40	Apalachicola East	2000-04-12						Historic	No
39	GA	14	Apalachicola East	2021-03-25	4.00	2.00	3.75	2.25	3.04	Moderate	Yes
40	GA	5	Apalachicola East	1939-04-05						Historic	No
41	GA	7	Apalachicola East	1989-04-08						Historic	No

Population #	State	EOs	RU	Date of Last Obs	A	R	H	T	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)
42	GA	55	Apalachicola East	2021-04-28	3.00	2.00	2.75	1.00	2.13	Low	No
43	GA	46	Apalachicola East	2003-03-07	1.00	2.00	3.25	3.50	2.38	Low	No
44	GA	67	Altamaha	2021-12-01						Safeguarded	Yes
45	GA	45, 47, 48	Altamaha	2021-04-29	4.00	2.00	3.34	3.37	3.34	High	Yes
46	GA	19, 25	Altamaha	2021-03-13	4.00	2.50	2.63	2.00	2.85	Moderate	Yes
47	GA	62	Altamaha	2021-04-29	4.00	4.00	3.50	2.88	3.54	High	No
48	GA	16	Altamaha	2017-03-02	1.00	4.00	3.00	1.00	1.85	Low	No
49	GA	54	Altamaha	2016-03-31	4.00	3.00	3.25	3.25	3.46	High	No
50	GA	24	Altamaha	1995-06-00						Historic	No
51	GA	23	Altamaha	2021-04-08	3.00	2.00	3.50	1.00	2.26	Low	Yes
52*	GA	58	Altamaha	2016-06-00	1.00	2.00	3.25	3.50	2.38	Low	No
53	GA	41	Altamaha	2010-03-22	3.00	3.00	3.25	3.75	3.29	High	No
54	GA	43	Altamaha	2001-03-22						Historic	No
55	GA	53	Altamaha	2008-04-02	1.00	4.00	2.25	3.25	2.47	Low	No
56	GA	42	Altamaha	2001-03-22						Historic	No
57	GA	4	Savannah West	2000-03-16						Historic	No
58	GA	1	Savannah West	2021-04-15	4.00	4.00	3.88	2.75	3.57	High	No
59	SC	99998, 99999	Savannah East	2021-03-26						No Data	No
60	SC	39825	Savannah East	Unknown						Historic	No

Population #	State	EOs	RU	Date of Last Obs	A	R	H	T	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)
61	SC	15469, 15470, 37089, 37090, 37091, 37092, 37093, 37094, 37095, 37096, 37097, 39800, 39807, 39808, 39809, 39810, 39811, 39813, 39814, 39815, 39816, 39817, 39818, 39820, 39821, 39822, 39824, 39849, 39850, 39851, 39853	Savannah East	2021-03-25	4.00	1.86	2.96	1.70	2.70	Moderate	No
62	SC	15467	Savannah East	2021-03-11	3.00	1.00	3.25	3.00	2.70	Moderate	No

APPENDIX D – PREDICTED URBANIZATION OUTPUT FROM SLEUTH MODEL AND ADJUSTMENT SCORES

Table displays predicted percent urbanization by high probability (H), status quo (SQ), and associated resiliency score adjustments (RA) for each population.

Pop #	Current	2040 >1% (H)	2080 >1% (H)	2040 >40-50% (H)	2040 >70-80% (H)	2080 >40-50% (H)	2080 >70-80% (H)	2040 >1% (SQ)	2080 >1% (SQ)	2040 >40-50% (SQ)	2040 >70-80% (SQ)	2080 >40-50% (SQ)	2080 >70-80% (SQ)	2040 >1% (RA)	2080 >1% (RA)	2040 >40-50% (RA)	2040 >70-80% (RA)	2080 >40-50% (RA)	2080 >70-80% (RA)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
13	32.9	66.1	88.7	54.0	48.1	80.9	75.6	33.1	55.7	21.0	15.2	48.0	42.6	-0.6	-0.8	-0.6	-0.6	-0.8	-0.8
14	0.0	2.3	15.3	0.0	0.0	3.0	2.9	2.3	15.3	0.0	0.0	3.0	2.9	-0.2	-0.6	0	0	-0.2	-0.2
15	0.0	1.2	7.0	0.0	0.0	2.2	0.4	1.2	7.0	0.0	0.0	2.2	0.4	-0.2	-0.4	0	0	-0.2	-0.2
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
20	0.0	0.0	22.2	0.0	0.0	3.8	0.7	0.0	22.2	0.0	0.0	3.8	0.7	0	-0.6	0	0	-0.2	-0.2
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
22	0.0	1.3	10.1	0.5	0.2	7.8	7.0	1.3	10.1	0.5	0.2	7.8	7.0	-0.2	-0.6	-0.2	-0.2	-0.4	-0.4
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0

Pop #	Current	2040 >1% (H)	2080 >1% (H)	2040 >40-50% (H)	2040 >70-80% (H)	2080 >40-50% (H)	2080 >70-80% (H)	2040 >1% (SQ)	2080 >1% (SQ)	2040 >40-50% (SQ)	2040 >70-80% (SQ)	2080 >40-50% (SQ)	2080 >70-80% (SQ)	2040 >1% (RA)	2080 >1% (RA)	2040 >40-50% (RA)	2040 >70-80% (RA)	2080 >40-50% (RA)	2080 >70-80% (RA)
24	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0	-0.2	0	0	0	0
25	0.0	6.5	11.8	1.9	0.4	11.7	11.7	6.5	11.8	1.9	0.4	11.7	11.7	-0.4	-0.6	-0.2	-0.2	-0.6	-0.6
26	25.8	60.3	67.7	45.9	40.6	67.0	65.4	34.6	42.0	20.1	14.9	41.3	39.6	-0.6	-0.8	-0.6	-0.6	-0.8	-0.6
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
29	0.0	48.3	87.3	29.0	23.0	69.5	63.2	48.3	87.3	29.0	23.0	69.5	63.2	-0.8	-0.8	-0.6	-0.6	-0.8	-0.8
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
35	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0	-0.6	0	0	0	0
36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
39	1.2	10.6	23.1	10.5	10.0	21.3	19.7	9.4	21.9	9.2	8.8	20.1	18.5	-0.4	-0.6	-0.4	-0.4	-0.6	-0.6
40	3.1	9.5	18.6	6.9	6.1	13.4	12.0	6.4	15.5	3.8	3.0	10.3	8.8	-0.4	-0.6	-0.2	-0.2	-0.6	-0.4
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
46	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0	-0.2	0	0	0	0
47	0.0	0.0	25.7	0.0	0.0	17.2	14.1	0.0	25.7	0.0	0.0	17.2	14.1	0	-0.6	0	0	-0.6	-0.6
48	11.6	88.3	95.3	73.5	67.1	95.1	92.1	76.7	83.7	61.8	55.4	83.5	80.4	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
49	1.0	49.3	66.2	27.4	23.2	53.4	48.2	48.3	65.2	26.4	22.2	52.4	47.2	-0.8	-0.8	-0.6	-0.6	-0.8	-0.8
50	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0	-0.2	0	0	0	0

Pop #	Current	2040 >1% (H)	2080 >1% (H)	2040 >40-50% (H)	2040 >70-80% (H)	2080 >40-50% (H)	2080 >70-80% (H)	2040 >1% (SQ)	2080 >1% (SQ)	2040 >40-50% (SQ)	2040 >70-80% (SQ)	2080 >40-50% (SQ)	2080 >70-80% (SQ)	2040 >1% (RA)	2080 >1% (RA)	2040 >40-50% (RA)	2040 >70-80% (RA)	2080 >40-50% (RA)	2080 >70-80% (RA)
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
52*	10.4	99.2	99.2	96.2	91.7	99.2	99.2	88.8	88.8	85.8	81.3	88.8	88.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
53	0.0	16.5	51.1	7.6	4.3	37.4	34.6	16.5	51.1	7.6	4.3	37.4	34.6	-0.6	-0.8	-0.4	-0.2	-0.6	-0.6
54	0.0	22.4	89.3	11.3	7.2	73.9	64.6	22.4	89.3	11.3	7.2	73.9	64.6	-0.6	-0.8	-0.6	-0.4	-0.8	-0.8
55	4.7	47.1	73.2	39.0	33.1	46.9	45.1	42.3	68.5	34.3	28.4	42.2	40.4	-0.8	-0.8	-0.6	-0.6	-0.8	-0.8
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
57	0.0	0.0	60.8	0.0	0.0	34.2	26.5	0.0	60.8	0.0	0.0	34.2	26.5	0	-0.8	0	0	-0.6	-0.6
58	16.6	89.2	92.1	79.8	73.8	91.8	90.5	72.6	75.5	63.1	57.1	75.2	73.9	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
60	0.0	0.0	14.5	0.0	0.0	0.0	0.0	0.0	14.5	0.0	0.0	0.0	0.0	0	-0.6	0	0	0	0
61	30.3	63.8	80.9	54.5	51.1	74.4	70.8	33.6	50.6	24.2	20.8	44.1	40.5	-0.6	-0.8	-0.6	-0.6	-0.8	-0.8
62	0.0	12.2	40.2	7.3	5.6	29.6	24.7	12.2	40.2	7.3	5.6	29.6	24.7	-0.6	-0.8	-0.4	-0.4	-0.6	-0.6

* Population previously identified as relict trillium but confirmed as different species in 2022.

APPENDIX E – PREDICTED LAND USE CHANGE OUTPUT FROM THE FORE-SCE MODEL AND ADJUSTMENT SCORES

Table displays two scenarios from the FORE-SCE model projection. The A2 is reflective of RCP 8.5 and a higher emissions scenario based on high economic growth and very high population growth globally. The B2 is reflective of RCP 4.5 and a lower emissions scenario based on the lowest US population growth and a focus on environmental protections.

Population	(A2) Habitat Change (acre) 2021	(A2) Habitat Change (acre) 2040	(A2) Habitat Change (acre) 2080	(B2) Habitat Change (acre) 2021	(B2) Habitat Change (acre) 2040	(B2) Habitat Change (acre) 2080	(A2) Adjustment 2040	(A2) Adjustment 2080	(B2) Adjustment 2040	(B2) Adjustment 2080
1	166.44	39.38	37.11	196.72	7.67	-22.23	0	0	0	-0.6
2	390.82	47.39	-55.91	382.20	-75.95	34.60	0	-0.6	-0.6	0
3	184.40	45.24	-32.85	217.58	63.78	-8.78	0	0	0	0
4	102.56	-15.44	42.21	111.58	70.70	-6.44	-0.6	0	0	0
5	236.10	0.53	-108.02	236.63	-31.93	-15.44	0	0	-0.6	0
6	112.30	4.05	-27.75	102.58	11.15	23.63	0	0	0	0
7	74.30	0.00	-21.23	119.50	-4.87	-63.42	0	0	-0.2	0
8	97.72	-51.93	-22.90	125.48	-1.15	-42.25	-0.8	0	-0.2	0
9	288.65	-10.45	-29.88	379.41	75.81	-44.27	-0.2	-0.6	0	0
10	33.00	0.00	-2.11	57.52	-16.80	-24.52	0	0	-0.6	0
11	85.59	-7.84	1.32	51.71	51.94	71.71	-0.4	0	0	0
12	122.99	-10.86	-17.65	92.27	11.38	8.09	-0.4	0	0	0
13	183.07	1.65	-29.23	195.66	62.02	65.33	0	0	0	0
14	51.43	0.00	20.43	51.43	0.51	9.45	0	0	0	0
15	347.31	-85.57	-29.10	222.54	35.30	54.90	-0.6	0	0	-0.2
16	273.89	16.03	0.56	289.91	-133.68	-56.38	0	0	-0.8	0
17	205.91	-31.22	-11.02	205.91	-15.24	-7.41	-0.6	0	-0.4	0
18	0.00	0.00	0.00	0.00	4.20	10.61	0	0	0	0
19	205.44	0.00	0.00	205.44	0.00	0.00	0	0	0	0
20	150.96	8.62	3.56	159.61	-53.73	0.00	0	0	-0.6	0
21	228.07	-13.23	-30.83	190.46	-39.36	38.55	-0.4	0	-0.6	0

Population	(A2) Habitat Change (acre) 2021	(A2) Habitat Change (acre) 2040	(A2) Habitat Change (acre) 2080	(B2) Habitat Change (acre) 2021	(B2) Habitat Change (acre) 2040	(B2) Habitat Change (acre) 2080	(A2) Adjustment 2040	(A2) Adjustment 2080	(B2) Adjustment 2040	(B2) Adjustment 2080
22	2865.51	-124.11	-189.21	2692.70	-174.48	50.77	-0.2	-0.8	-0.4	-0.4
23	234.55	-10.31	0.00	219.10	14.53	0.00	-0.2	0	0	0
24	231.22	19.72	4.28	214.81	-22.00	19.73	0	0	-0.6	0
25	632.93	0.00	-43.52	618.94	-1.46	-16.90	0	0	-0.2	0
26	227.62	22.74	22.74	250.36	-26.50	25.41	0	0	-0.6	0
27	54.98	0.00	0.00	54.98	0.00	0.00	0	0	0	0
28	7.39	0.00	0.00	7.39	0.00	0.00	0	0	0	-0.4
29	168.82	-18.41	-22.29	183.17	-14.69	0.00	-0.6	0	-0.4	0
30	152.13	0.00	0.00	152.13	0.00	0.00	0	-0.6	0	0
31	52.95	15.44	11.97	68.39	-3.65	0.00	0	0	-0.4	0
32	48.30	0.00	0.00	32.93	15.37	15.37	0	0	0	0
33	186.07	55.07	37.68	255.10	1.08	-41.54	0	0	0	0
34	93.02	35.45	73.28	156.28	-44.72	-19.84	0	0	-0.6	0
35	113.68	63.07	70.27	158.77	-5.71	25.18	0	0	-0.2	0
36	162.19	-15.44	-3.41	162.19	-28.71	-42.04	-0.4	0	-0.6	0
37	170.66	0.00	-8.78	186.10	12.74	2.49	0	0	0	0
38	107.02	14.93	0.05	137.40	-14.63	-23.26	0	-0.6	-0.6	0
39	121.70	15.44	-14.62	139.06	61.56	46.11	0	0	0	0
40	4580.74	-703.55	-3339.81	4866.79	10.44	7.93	-0.6	0	0	0
41	36.93	9.08	15.44	52.37	15.44	30.89	0	0	0	0
42	163.76	8.81	-53.86	133.39	-46.33	26.49	0	0	-0.6	0
43	51.06	0.00	0.00	51.06	44.07	47.51	0	0	0	0
44	117.20	0.00	0.00	117.20	0.00	0.00	0	0	0	-0.8
45	956.89	7.58	-53.51	958.84	57.40	36.52	0	0	0	0
46	406.32	15.44	-15.87	438.19	-23.66	-44.25	0	-0.6	-0.4	0
47	406.36	-15.44	-88.15	376.34	38.19	36.27	-0.2	0	0	0
48	522.26	-22.32	-282.59	554.43	30.30	42.61	-0.2	0	0	0

Population	(A2) Habitat Change (acre) 2021	(A2) Habitat Change (acre) 2040	(A2) Habitat Change (acre) 2080	(B2) Habitat Change (acre) 2021	(B2) Habitat Change (acre) 2040	(B2) Habitat Change (acre) 2080	(A2) Adjustment 2040	(A2) Adjustment 2080	(B2) Adjustment 2040	(B2) Adjustment 2080
49	104.10	0.00	0.00	71.12	17.53	17.53	0	0	0	0
50	36.43	-15.44	0.00	20.99	35.42	36.09	-0.8	0	0	0
51	34.12	0.00	15.44	34.12	0.00	0.00	0	0	0	0
52*	58.28	0.00	-37.86	49.28	-18.99	42.14	0	0	-0.6	-0.6
53	229.44	18.58	2.18	236.64	9.84	28.92	0	-0.6	0	0
54	145.35	0.00	-73.34	172.50	-31.17	-20.24	0	0	-0.6	0
55	201.44	0.00	-32.75	147.17	28.66	8.42	0	0	0	0
56	72.29	0.00	-18.88	47.10	13.67	13.67	0	0	0	0
57	60.81	0.00	-60.81	60.81	0.00	-0.73	0	0	0	0
58	78.63	-41.97	-78.63	78.63	0.00	0.00	-0.8	0	0	0
59	94.61	8.50	-3.46	85.54	17.57	9.85	0	0	0	-0.6
60	496.13	-41.62	-454.24	474.73	48.33	40.95	-0.4	-0.4	0	0
61	700.55	-483.39	-646.05	936.20	-151.52	-249.17	-0.8	0	-0.6	0
62	108.85	-62.52	-108.85	112.52	-57.16	-10.83	-0.8	0	-0.8	0

* Population previously identified as relict trillium but confirmed as different species in 2022.

APPENDIX F – FUTURE CONDITION POPULATION DATA 2040

Pop #	State	RU	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)	Scenario 1 Resiliency Score	Scenario 1 Resiliency Class	Scenario 2 Resiliency Score	Scenario 2 Resiliency Class	Scenario 3 Resiliency Score	Scenario 3 Resiliency Class	Scenario 4 Resiliency Score	Scenario 4 Resiliency Class
1	AL	Apalachicola West	3.84	High	No	3.44	High	3.44	High	3.24	Moderate	3.44	High
2	AL	Apalachicola West	2.75	Moderate	No	1.75	Low	2.35	Low	2.15	Low	2.35	Low
3	AL	Choctawhatchee		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
4	AL	Choctawhatchee	2.34	Low	No	1.94	Low	1.34	Very Low	1.14	Very Low	1.34	Very Low
5	AL	Choctawhatchee	3.25	Moderate	No	2.25	Low	2.85	Moderate	2.65	Moderate	2.85	Moderate
6	AL	Choctawhatchee	2.97	Moderate	No	2.57	Moderate	2.57	Moderate	2.37	Low	2.57	Moderate
7	AL	Choctawhatchee	3.20	Moderate	No	2.60	Moderate	2.80	Moderate	2.60	Moderate	2.80	Moderate
8	AL	Choctawhatchee	2.42	Low	No	1.82	Low	1.22	Very Low	1.02	Very Low	1.22	Very Low
9	AL	Choctawhatchee	2.21	Low	No	1.81	Low	1.61	Very Low	1.41	Very Low	1.61	Very Low
10	AL	Apalachicola West	2.38	Low	Yes	1.58	Very Low	2.18	Low	2.18	Low	2.38	Low
11	AL	Apalachicola West	2.30	Low	No	1.90	Low	1.50	Very Low	1.30	Very Low	1.50	Very Low
12	AL	Apalachicola West	1.09	Very Low	No	0.69	Very Low	0.29	Very Low	0.09	Extirpated	0.29	Very Low
13	GA	Apalachicola East	2.75	Moderate	No	1.75	Low	1.75	Low	1.55	Very Low	1.75	Low
14	GA	Apalachicola East	2.01	Low	No	1.61	Very Low	1.61	Very Low	1.21	Very Low	1.61	Very Low
15	GA	Apalachicola East	2.34	Low	No	1.94	Low	1.34	Very Low	0.94	Very Low	1.34	Very Low
16	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
17	GA	Apalachicola East	3.08	Moderate	No	2.28	Low	2.08	Low	1.88	Low	2.08	Low
18	GA	Apalachicola East	2.54	Moderate	No	2.14	Low	2.14	Low	1.94	Low	2.14	Low
19	GA	Apalachicola East		Safeguarded	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
20	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded

Pop #	State	RU	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)	Scenario 1 Resiliency Score	Scenario 1 Resiliency Class	Scenario 2 Resiliency Score	Scenario 2 Resiliency Class	Scenario 3 Resiliency Score	Scenario 3 Resiliency Class	Scenario 4 Resiliency Score	Scenario 4 Resiliency Class
21	GA	Apalachicola East		Safeguarded	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
22	GA	Apalachicola East	3.46	High	No	2.46	Low	2.66	Moderate	2.46	Low	2.66	Moderate
23	GA	Apalachicola East	2.13	Low	No	1.73	Very Low	1.53	Very Low	1.33	Very Low	1.53	Very Low
24	GA	Apalachicola East	2.21	Low	No	1.21	Very Low	1.81	Low	1.61	Very Low	1.81	Low
25	GA	Apalachicola East		No Data	Yes	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
26	GA	Apalachicola East	3.51	High	Yes	2.11	Low	2.71	Moderate	2.71	Moderate	2.91	Moderate
27	GA	Apalachicola East	2.30	Low	Yes	2.10	Low	2.10	Low	2.10	Low	2.30	Low
28	GA	Apalachicola East	3.61	High	Yes	3.41	High	3.41	High	3.41	High	3.61	High
29	GA	Apalachicola East	2.13	Low	No	0.93	Very Low	0.73	Very Low	0.53	Very Low	0.93	Very Low
30	GA	Apalachicola East	3.28	High	Yes	3.08	Moderate	3.08	Moderate	3.08	Moderate	3.28	High
31	GA	Apalachicola East	2.38	Low	Yes	1.78	Low	2.18	Low	2.18	Low	2.38	Low
32	GA	Apalachicola East	1.68	Very Low	Yes	1.48	Very Low	1.48	Very Low	1.48	Very Low	1.68	Very Low
33	GA	Apalachicola East	2.34	Low	Yes	2.14	Low	2.14	Low	2.14	Low	2.34	Low
34	GA	Apalachicola East	2.34	Low	Yes	1.54	Very Low	2.14	Low	2.14	Low	2.34	Low
35	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
36	GA	Apalachicola East	2.38	Low	No	1.38	Very Low	1.58	Very Low	1.38	Very Low	1.58	Very Low
37	GA	Apalachicola East	2.88	Moderate	Yes	2.68	Moderate	2.68	Moderate	2.68	Moderate	2.88	Moderate

Pop #	State	RU	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)	Scenario 1 Resiliency Score	Scenario 1 Resiliency Class	Scenario 2 Resiliency Score	Scenario 2 Resiliency Class	Scenario 3 Resiliency Score	Scenario 3 Resiliency Class	Scenario 4 Resiliency Score	Scenario 4 Resiliency Class
38	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
39	GA	Apalachicola East	3.04	Moderate	Yes	2.44	Low	2.44	Low	2.44	Low	2.64	Moderate
40	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
41	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
42	GA	Apalachicola East	2.13	Low	No	1.13	Very Low	1.73	Very Low	1.53	Very Low	1.73	Very Low
43	GA	Apalachicola East	2.38	Low	No	1.98	Low	1.98	Low	1.78	Low	1.98	Low
44	GA	Altamaha		Safeguarded	Yes	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
45	GA	Altamaha	3.34	High	Yes	3.14	Moderate	3.14	Moderate	3.14	Moderate	3.34	High
46	GA	Altamaha	3.1	Moderate	Yes	2.50	Low	2.90	Moderate	2.90	Moderate	3.10	Moderate
47	GA	Altamaha	3.54	High	Yes	3.14	Moderate	2.94	Moderate	2.74	Moderate	2.94	Moderate
48	GA	Altamaha	1.85	Low	No	0.65	Very Low	0.45	Very Low	0.25	Very Low	0.45	Very Low
49	GA	Altamaha	3.46	High	No	2.46	Low	2.46	Low	2.06	Low	2.46	Low
50	GA	Altamaha		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
51	GA	Altamaha	2.26	Low	Yes	2.06	Low	2.06	Low	2.06	Low	2.26	Low
52*	GA	Altamaha	2.38	Low	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
53	GA	Altamaha	3.29	High	No	2.49	Low	2.49	Low	2.09	Low	2.49	Low
54	GA	Altamaha		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
55	GA	Altamaha	2.47	Low	No	1.47	Very Low	1.47	Very Low	1.07	Very Low	1.47	Very Low
56	GA	Altamaha		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
57	GA	Savannah West		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
58	GA	Savannah West	3.57	High	No	2.37	Low	1.57	Very Low	1.37	Very Low	1.57	Very Low
59	SC	Savannah East		No Data	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
60	SC	Savannah East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
61	SC	Savannah East	2.70	Moderate	No	1.30	Very Low	1.10	Very Low	1.10	Very Low	1.30	Very Low
62	SC	Savannah East	2.70	Moderate	No	1.10	Very Low	1.10	Very Low	0.70	Very Low	1.10	Very Low

* Population previously identified as relict trillium but confirmed as different species in 2022.

APPENDIX G – FUTURE CONDITION POPULATION DATA 2080

Pop #	State	RU	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)	Scenario 1 Resiliency Score	Scenario 1 Resiliency Class	Scenario 2 Resiliency Score	Scenario 2 Resiliency Class	Scenario 3 Resiliency Score	Scenario 3 Resiliency Class	Scenario 4 Resiliency Score	Scenario 4 Resiliency Class
1	AL	Apalachicola West	3.84	High	No	2.64	Moderate	3.24	Moderate	3.04	Moderate	3.24	Moderate
2	AL	Apalachicola West	2.75	Moderate	No	2.15	Low	1.55	Very Low	1.35	Very Low	1.55	Very Low
3	AL	Choctawhatchee		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
4	AL	Choctawhatchee	2.34	Low	No	1.74	Very Low	1.74	Very Low	1.54	Very Low	1.74	Very Low
5	AL	Choctawhatchee	3.25	Moderate	No	2.65	Moderate	2.65	Moderate	2.45	Low	2.65	Moderate
6	AL	Choctawhatchee	2.97	Moderate	No	2.37	Low	2.37	Low	2.17	Low	2.37	Low
7	AL	Choctawhatchee	3.20	Moderate	No	2.60	Moderate	2.60	Moderate	2.40	Low	2.60	Moderate
8	AL	Choctawhatchee	2.42	Low	No	1.82	Low	1.82	Low	1.62	Very Low	1.82	Low
9	AL	Choctawhatchee	2.21	Low	No	1.61	Very Low	1.01	Very Low	0.81	Very Low	1.01	Very Low
10	AL	Apalachicola West	2.38	Low	Yes	2.18	Low	2.18	Low	2.18	Low	2.38	Low
11	AL	Apalachicola West	2.30	Low	No	1.70	Very Low	1.70	Very Low	1.50	Very Low	1.70	Very Low
12	AL	Apalachicola West	1.09	Very Low	No	0.49	Very Low	0.49	Very Low	0.29	Very Low	0.49	Very Low
13	GA	Apalachicola East	2.75	Moderate	No	1.35	Very Low	1.35	Very Low	1.15	Very Low	1.35	Very Low
14	GA	Apalachicola East	2.01	Low	No	1.21	Very Low	1.21	Very Low	0.61	Very Low	1.21	Very Low
15	GA	Apalachicola East	2.34	Low	No	1.34	Very Low	1.54	Very Low	1.14	Very Low	1.54	Very Low
16	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
17	GA	Apalachicola East	3.08	Moderate	No	2.48	Low	2.48	Low	2.28	Low	2.48	Low
18	GA	Apalachicola East	2.54	Moderate	No	1.94	Low	1.94	Low	1.74	Very Low	1.94	Low
19	GA	Apalachicola East		Safeguarded	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded

Pop #	State	RU	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)	Scenario 1 Resiliency Score	Scenario 1 Resiliency Class	Scenario 2 Resiliency Score	Scenario 2 Resiliency Class	Scenario 3 Resiliency Score	Scenario 3 Resiliency Class	Scenario 4 Resiliency Score	Scenario 4 Resiliency Class
20	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
21	GA	Apalachicola East		Safeguarded	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
22	GA	Apalachicola East	3.46	High	No	2.06	Low	1.66	Very Low	1.26	Very Low	1.66	Very Low
23	GA	Apalachicola East	2.13	Low	No	1.53	Very Low	1.53	Very Low	1.33	Very Low	1.53	Very Low
24	GA	Apalachicola East	2.21	Low	No	1.61	Very Low	1.61	Very Low	1.21	Very Low	1.61	Very Low
25	GA	Apalachicola East		No Data	Yes	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
26	GA	Apalachicola East	3.51	High	Yes	2.51	Moderate	2.51	Moderate	2.51	Moderate	2.71	Moderate
27	GA	Apalachicola East	2.30	Low	Yes	2.10	Low	2.10	Low	2.10	Low	2.30	Low
28	GA	Apalachicola East	3.61	High	Yes	3.01	Moderate	3.41	High	3.41	High	3.61	High
29	GA	Apalachicola East	2.13	Low	No	1.13	Very Low	1.13	Very Low	1.13	Very Low	1.33	Very Low
30	GA	Apalachicola East	3.28	High	Yes	3.08	Moderate	2.48	Low	2.48	Low	2.68	Moderate
31	GA	Apalachicola East	2.38	Low	Yes	2.18	Low	2.18	Low	2.18	Low	2.38	Low
32	GA	Apalachicola East	1.68	Very Low	Yes	1.48	Very Low	1.48	Very Low	1.48	Very Low	1.68	Very Low
33	GA	Apalachicola East	2.34	Low	Yes	2.14	Low	2.14	Low	2.14	Low	2.34	Low
34	GA	Apalachicola East	2.34	Low	Yes	2.14	Low	2.14	Low	2.14	Low	2.34	Low
35	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
36	GA	Apalachicola East	2.38	Low	No	1.78	Low	1.78	Low	1.58	Very Low	1.78	Low

Pop #	State	RU	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)	Scenario 1 Resiliency Score	Scenario 1 Resiliency Class	Scenario 2 Resiliency Score	Scenario 2 Resiliency Class	Scenario 3 Resiliency Score	Scenario 3 Resiliency Class	Scenario 4 Resiliency Score	Scenario 4 Resiliency Class
37	GA	Apalachicola East	2.88	Moderate	Yes	2.68	Moderate	2.68	Moderate	2.68	Moderate	2.88	Moderate
38	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
39	GA	Apalachicola East	3.04	Moderate	Yes	2.24	Low	2.24	Low	2.24	Low	2.44	Low
40	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
41	GA	Apalachicola East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
42	GA	Apalachicola East	2.13	Low	No	1.53	Very Low	1.53	Very Low	1.33	Very Low	1.53	Very Low
43	GA	Apalachicola East	2.38	Low	No	1.78	Low	1.78	Low	1.58	Very Low	1.78	Low
44	GA	Altamaha		Safeguarded	Yes	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
45	GA	Altamaha	3.34	High	Yes	3.14	Moderate	3.14	Moderate	3.14	Moderate	3.34	High
46	GA	Altamaha	3.0	Moderate	Yes	2.90	Moderate	2.30	Low	2.10	Low	2.50	Low
47	GA	Altamaha	3.54	High	Yes	2.34	Low	2.34	Low	2.14	Low	2.34	Low
48	GA	Altamaha	1.85	Low	No	0.45	Very Low	0.45	Very Low	0.25	Very Low	0.45	Very Low
49	GA	Altamaha	3.46	High	No	2.06	Low	2.06	Low	1.86	Low	2.06	Low
50	GA	Altamaha		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
51	GA	Altamaha	2.26	Low	Yes	2.06	Low	2.06	Low	2.06	Low	2.26	Low
52*	GA	Altamaha	2.38	Low	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
53	GA	Altamaha	3.29	High	No	2.09	Low	1.49	Very Low	1.09	Very Low	1.49	Very Low
54	GA	Altamaha		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
55	GA	Altamaha	2.47	Low	No	1.07	Very Low	1.07	Very Low	0.87	Very Low	1.07	Very Low
56	GA	Altamaha		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
57	GA	Savannah West		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
58	GA	Savannah West	3.57	High	No	2.17	Low	2.17	Low	1.97	Low	2.17	Low
59	SC	Savannah East		No Data	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded

Pop #	State	RU	Current Resiliency Score	Current Resiliency Class	Protected (Y/N)	Scenario 1 Resiliency Score	Scenario 1 Resiliency Class	Scenario 2 Resiliency Score	Scenario 2 Resiliency Class	Scenario 3 Resiliency Score	Scenario 3 Resiliency Class	Scenario 4 Resiliency Score	Scenario 4 Resiliency Class
60	SC	Savannah East		Historic	No	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
61	SC	Savannah East	2.70	Moderate	No	1.70	Very Low	1.70	Very Low	1.70	Very Low	1.90	Low
62	SC	Savannah East	2.70	Moderate	No	1.50	Very Low	1.50	Very Low	1.10	Very Low	1.50	Very Low

* Population previously identified as relict trillium but confirmed as different species in 2022.