

**Species Status Assessment
For
Venus Flytrap
(*Dionaea muscipula*)
Version 1.1**



Venus flytrap (*Dionaea muscipula*), Brunswick County, NC. Photo Credit: Dale Suiter

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We appreciate the time and effort of those dedicated to learning and implementing the SSA Framework, which resulted in a more robust assessment and final report.

Suggested reference:

U.S. Fish and Wildlife Service. 2023. Species status assessment report for the Venus Flytrap (*Dionaea muscipula*). Version 1.1. March 2023. Atlanta, GA.

EXECUTIVE SUMMARY

Venus flytrap (*Dionaea muscipula*) is a perennial herbaceous vascular plant species endemic to southeastern North Carolina and northeastern South Carolina. It has a historical range within approximately 100 miles (161 kilometers) of Wilmington, NC. The carnivorous plant is well known for its ability to trap prey in its distinctive leaves that trap and digest arthropods. Venus flytrap occurs in wetland habitats in the Outer and Inner Coastal Plain and Sandhills ecoregions. In the Outer Coastal Plain, where it is more common, large populations of Venus flytrap occur in sandy pine savannas and wet pine flatwoods, and in the Sandhills region, Venus flytrap plants are limited to seeps between evergreen shrub bogs along small creeks and pine/scrub oak uplands.

This report summarizes the results of a species status assessment (SSA) conducted for Venus flytrap. Venus flytrap is an At-Risk species, and the U.S. Fish and Wildlife Service (Service) received a petition to list this species as an endangered species on October 21, 2016. This SSA report contains the best scientific and commercial information available regarding the species' biology and factors that influence the species' viability.

The greatest threats to Venus flytrap are associated with various actions that modify or destroy habitat such as fire suppression. Other threats that modify or destroy habitat include land conversion such as conversion to agriculture (including silviculture), residential and commercial development and right-of-way maintenance. Other stressors that could have a negative effect on the species include poaching, small population size, nonnative invasive species, herbivory, and climate change. Likewise, there are many ongoing positive actions that benefit Venus flytrap such as habitat protection and management, state laws that protect Venus flytrap, international recognition by conservation organizations such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the International Union for Conservation of Nature, horticultural availability of ethically grown plants and grass roots efforts to work with land owners and raise awareness about Venus flytrap conservation.

For the purpose of this species status assessment, we defined resiliency as the ability of Venus flytrap to sustain populations in the habitats where it occurs over time. Each population of Venus flytrap needs to be able to withstand, or be resilient to, stochastic events or disturbances (e.g., drought, flooding, fluctuations in seed viability, etc.). To have high resiliency, these populations need to have an adequate number of individuals, cover a large enough area (multiple occurrences within a population), and have connectivity within a population so that a localized event does not eliminate a population. To assess resiliency, we considered a combination of factors including population size (number of individual plants), the number of subpopulations within each population, the area occupied by a population (acreage), and management regime.

Of 140 known Venus flytrap populations, 74 are considered extant and 66 are considered extirpated. Eight populations (11%) have high resiliency, 10 populations (14%) have medium resiliency, and 56 (76%) have low resiliency. The most robust populations occur in the Outer Coastal Plain (all eight highly resilient and 8 of the 10 populations with medium resiliency). Venus flytrap was likely never widespread through the Inner Coastal Plain and Sandhills like it is in the Outer Coastal Plain.

Two-thirds of all known plants (584,700 of 880,300) occur at the three largest populations. These three populations occur on a preserve owned by The Nature Conservancy, a state-owned game land, and a military base. The nature preserve and game land are protected from future development and managed with prescribed fire and are expected to remain in good condition. The third largest Venus flytrap population occurs on a military base where regular fire has maintained this population; however, management of the military base could change so the long-term protection of this population is less certain. While 66 populations are considered extirpated, we do not know the original population sizes nor do we know the historical resiliency of those populations that no longer exist.

With regards to representation, the fact that Venus flytrap persists in different plant communities within the Outer and Inner Coastal Plain and the Sandhills with different environmental conditions between the ecoregions demonstrates moderate adaptive capacity. The large number of low resiliency and extirpated populations indicate reduced representation across ecoregions. Overall, Venus flytrap has multiple medium and highly resilient populations in the Outer Coastal Plain and some medium and low resilient populations in the Sandhills, thus enabling the species to withstand catastrophic events.

For our future conditions analysis, we looked at how the threats of development and climate change could affect the resiliency of Venus flytrap populations at decadal intervals 50 years into the future. We examined how habitat loss and management with prescribed fire can affect overall species' viability in the future, and how a population's protected status factored into future management. We found only minor differences to population resilience under different climate futures (SSP2 or the SSP5 scenarios), and we saw no change in the number and distribution of highly resilient populations into the future. Management with prescribed fire is critical to species' viability. Since protected populations are currently well managed with prescribed fire, we assume a commitment to continue management into the future. Five highly resilient populations are located on protected lands and three are located on military lands; therefore, they will likely be managed with prescribed fire and maintain high resiliency into the future. We saw a slight increase in the number and distribution of medium resiliency populations when management with prescribed fire is increased in the future. There are many populations that fall into the low or very low resiliency categories in the future, however these populations are small, isolated, and together they consist of only 5% of the area occupied by the species. We do not know the genetic contribution of these small, isolated populations.

Eight (11%) out of 74 extant Venus flytrap populations are predicted to remain highly resilient 50 years into the future, and 10 to 16 (13%-20%) populations are predicted to remain in medium resiliency condition 50 years into the future. These medium and highly resilient populations represent over 98% of the known plants and 95% of the total area currently occupied by the species. Species' redundancy could be reduced if the populations in the Sandhills are not adequately managed into the future, thus potentially limiting the species entirely to the Outer Coastal Plain. While the Venus flytrap occupies a narrow geographic range, species' representation, or adaptive capacity, is predicted to remain constant, provided that the protected populations remain managed with prescribed fire into the future. Management with prescribed fire is the key to maintaining Venus flytrap viability into the future.

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CHAPTER 1: INTRODUCTION

1.1 Background

Venus flytrap (*Dionaea muscipula* J. Ellis) is a perennial herbaceous vascular plant species endemic to southeastern North Carolina (NC) and northeastern South Carolina (SC). The carnivorous plant is well known for its ability to trap prey in its distinctive leaves that trap and digest arthropods.

This report summarizes the results of a species status assessment (SSA) conducted for Venus flytrap. Venus flytrap is an At-Risk species, and the U.S. Fish and Wildlife Service (Service) received a petition to list this species as an endangered species on October 21, 2016. This SSA report contains the best scientific and commercial information available regarding the species' biology and factors that influence the species' viability.

1.2 Analytical Framework

The SSA report is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available, and to support all functions of the Service's Endangered Species Program. As such, the SSA report is a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews, will be based upon as the species is evaluated under the Act.

This SSA report for the Venus flytrap is intended to provide the biological support for a potential decision to list the species as endangered or threatened. The process and this SSA report do not represent a decision by the Service whether or not to list a species under the Act. Instead, this SSA report provides a review of the best scientific and commercial information available strictly related to the biological status of the Venus flytrap. The decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and a decision will be announced in the *Federal Register*.

Using the SSA framework (Figure 1-1), we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (together the "3Rs") (Shaffer and Stein, 2000, pp. 308-311; Wolf et al. 2015, entire; Smith et al. 2018, entire). In this assessment, we generally define viability as the ability of the species to sustain populations in the wild within a biologically meaningful timeframe: in this case, 50 years. Fifty years is also a period that allows us to reasonably predict the potential effects of the various stressors within the range of the species as well as predict species response to those stressors.

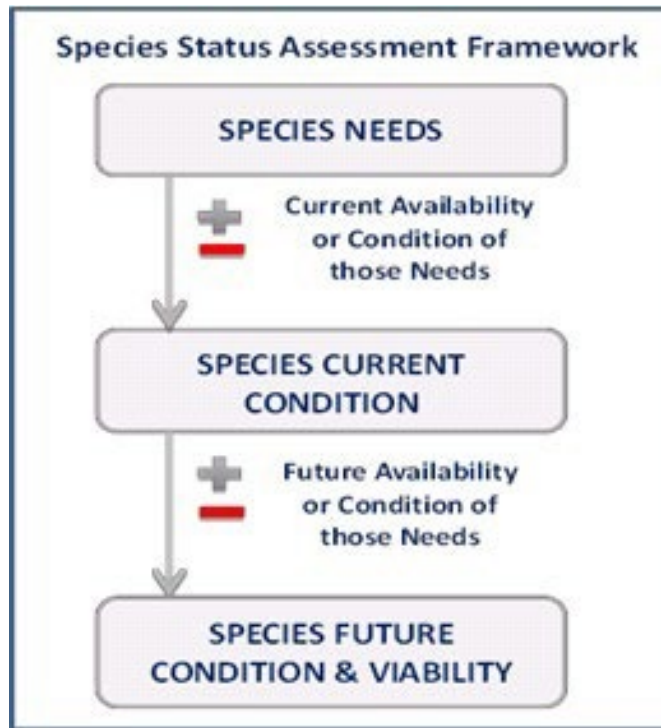


Figure 1-1. Species Status Assessment Framework

Resiliency, representation and redundancy (the 3Rs) are defined as follows:

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.

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 (Nicotra et al. 2015, p. 1270; Beever et al.

2016, p. 132). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Zackay 2007, p. 1, Crandall et al. 2000, pp. 290–291; Sgro et al. 2011, p. 327).

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 that might exist across the range and environmental or ecological variation across the range) and smaller-scale variation (which might include measures of between subpopulation genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to migrate to 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 SSAs, we assess all three facets to the best of our ability based on available data.

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 health and for which adaptation is unlikely (Mangel 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 species with small ranges, at the species level.

The 3Rs, and their core autecological parameters of abundance, distribution and diversity, are the key characteristics that contribute to a species' ability to sustain populations in the wild over time. When combined across populations, they measure the health of the species as a whole. The decision whether to list a species is based *not* on a prediction of the most likely future for the species, but rather on an assessment of the species' risk of extinction. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future under a range of scenarios to account for the uncertainty of the species' future. We evaluate the current biological status of the species by assessing the primary factors negatively and positively affecting the species to describe its current condition in terms of the 3Rs. We then evaluate the future biological status by describing a range of plausible future scenarios representing a range of conditions for the primary factors affecting the species and forecasting the most likely future condition for each scenario in terms of the 3Rs. As a matter of practicality, the full range of potential future scenarios and the range of potential future conditions for each potential scenario are too large to individually describe and analyze. These scenarios do not include all possible futures, but rather include specific plausible scenarios that represent examples from the continuous spectrum of possible futures. This future scenario analysis is intended to inform the determination of the risk that extinction within the timeframe analyzed.

To evaluate the current and future biological status of the Venus flytrap, we assessed a range of conditions that reflect the species' resiliency, redundancy, and representation. This document is

a compilation of the best available scientific and commercial information and a description of limiting factors to Venus flytrap viability, and includes:

1. A summary of Venus flytrap life history and ecology, with an assessment of individual and population-level Venus flytrap resource needs and description of the Venus flytrap historical and current distribution (Chapter 2)
2. A review of factors hypothesized to contribute to Venus flytrap current status, including metrics of resiliency, redundancy, and representation that characterize Venus flytrap current condition (Chapter 3)
3. Information about factors affecting Venus flytrap (Chapter 4)
4. Forecasted future status of the species and summary of species viability (Chapter 5)
5. References
6. Appendices with details of the analyses used for Current and Future Conditions

CHAPTER 2: SPECIES INFORMATION

2.1 Species Description

Venus flytrap (*Dionaea muscipula*) is one of the most widely recognized plant species on earth. Darwin (1875, p. 286) referred to it as “one of the most wonderful plants in the world.” Bailey and McPherson (2012, p. 9) call it “the most iconic plant in the world.”

Venus flytrap is a small, low-growing perennial herb that forms a basal rosette of distinct leaves that are attached to a short rhizome. The leaf blade consists of two somewhat kidney-shaped, hinged, lobes up to 25 mm long with stiff marginal hairs to 8 mm long. When trigger hairs are stimulated, the two lobes snap closed, trapping insects between them. The leaf petioles (the portion below the trap) are winged and 2-7 cm long. The flowers are arranged in an umbellate cyme (a central flower surrounded by additional flowers forming the general shape of an umbrella) at the top of a 10-30 cm tall scape (flowering stem). The five white petals are 11-13 mm long (Figure 2-1). The flowers contain one stigma and 10-20 stamens. The capsule is 3-4 mm long. This species flowers from May to June and the fruits mature in June and July (Hamon et al. 2021a, p. 7; Mellichamp in FNA6 2015; Radford et al. 1968, p. 518; Weakley 2020, p. 1055).

Venus flytrap is the only member of the genus *Dionaea*. Due to the unique shape of its leaves and their ability to trap insects, it would be difficult to confuse it with any other species (Roberts and Oosting 1958, p. 217). Venus flytrap leaves appear to have seasonal differences. Winter leaves are short with broad petioles and lay on the ground while summer leaves are longer with more narrow petioles and are more upright. Leaves emerge from an underground bulb-like rhizome which makes this species well adapted for the fires that maintain the habitat where it occurs (Bailey and McPherson 2013, p. 106; Roberts and Oosting 1958, p. 217). Venus flytrap has a weak root system consisting of a few short unbranched roots with long, persistent root hairs (Roberts and Oosting 1958, p. 217).



Figure 2-1. Photos of Venus flytrap (*Dionaea muscipula*) plant. Photo Credit: Dale Suiter

2.2 Taxonomy

Venus flytrap was most likely first collected by John Bartram, Colonial botanist to King George III. Ellis (1770, p. 38) wrote that in 1765 Peter Collinson sent him a dried specimen that he had received from Bartram. This species was first described by John Ellis in a letter to the printer of The St. James's Chronicle (a London newspaper), in the issue dated September 1-3, 1768, and further described in more detail in a letter to Sir Carl Linnaeus dated September 23, 1769 (Nelson 1989, p. 250-252; Ellis 1770, entire).

The genus *Dionaea* after Dione, the Greek goddess of beauty, was suggested by Swedish botanist Daniel Solander likely after dissecting a dried specimen that was collected by John Bartram and sent to him by horticulturist Peter Collinson in 1763 (Bailey and McPherson, 2012 p. 11, 397-398).

Dionaea is monotypic genus in the sundew family (Droseraceae), meaning that there is only one species in the genus. The sundew family consists of three genera of carnivorous plants: *Drosera*, *Dionaea*, and *Aldrovanda*. Members of this plant family are found on all continents except Antarctica. The species name, *muscipula*, derives from the Latin word for “mousetrap.” The species, *D. muscipula*, is one of the most recognized plant species in the world and there is no evidence in the literature to suggest that it is not a valid species. Due to its popularity in the horticulture trade, Venus flytrap has been the subject of much selective breeding and there are many named varieties (Bailey and McPherson 2012, pp. 143-333).

According to the Integrated Taxonomic Information System (ITIS), the authoritative taxonomic information on plants, animals, fungi, and microbes of North America and the world, the taxonomy of Venus flytrap is as follows (ITIS, accessed Sept. 16, 2021):

Kingdom	Plantae
Division	Tracheophyta
Class	Magnoliopsida
Order	Caryophyllales
Family	Droseraceae
Genus	<i>Dionaea</i>
Species	<i>muscipula</i>

Venus flytrap also goes by the following common names: Venus flytrap, Venus fly trap, Venus's-flytrap, meadow-clam, tippitiwitchet (ITIS, accessed Sept. 16, 2021, Weakley 2020, p. 1055).

2.3 Life History and Life Cycle

Venus flytrap is a long-lived perennial flowering plant species. Specimens have survived in cultivation for at least 25 years (Bailey and McPherson 2013, p. 105). Seedlings take three to four or more years to reach reproductive maturity, or ability to flower (Bailey and McPherson 2012, p. 105; Roberts and Oosting 1958, p. 202).

The life cycle of Venus flytrap consists of four stages: adult (flowering) plant, seed, seedling and juvenile plant (Figure 2-2). Venus flytrap flowers from mid-May to early-July (Hamon et al.

2019, p. 142). Recent research confirmed that the species is self-compatible meaning pollen can fertilize an ovary on the same plant. Due to the timing of ripe pollen and receptive stigmas, the species is dependent on pollinators for sexual reproduction (Hamon 2022, p. 84-89). Venus flytrap has a generalist pollination system in which key players likely include bumble bees, non-native honey bees, sweat bees, and beetles (Hamon 2022, p. 86). Little is known about the foraging range of known pollinators however, it is believed to be relatively short for some species like sweat bees and possibly longer (greater than 1 kilometer, km (0.62 miles, mi)) for honey bees and small bumble bees (E. Youngsteadt, pers. comm., email, Nov. 20, 2021). Butterflies, while not necessarily the most efficient pollinators, tend to travel far distances and could promote gene flow between distant patches (L. Hamon, pers. comm., email, Nov. 22, 2021). Heavy shading affects flower development and seed is not set on plants that are intensely shaded (Roberts and Oosting 1958, p. 215).

Venus flytrap Life Cycle

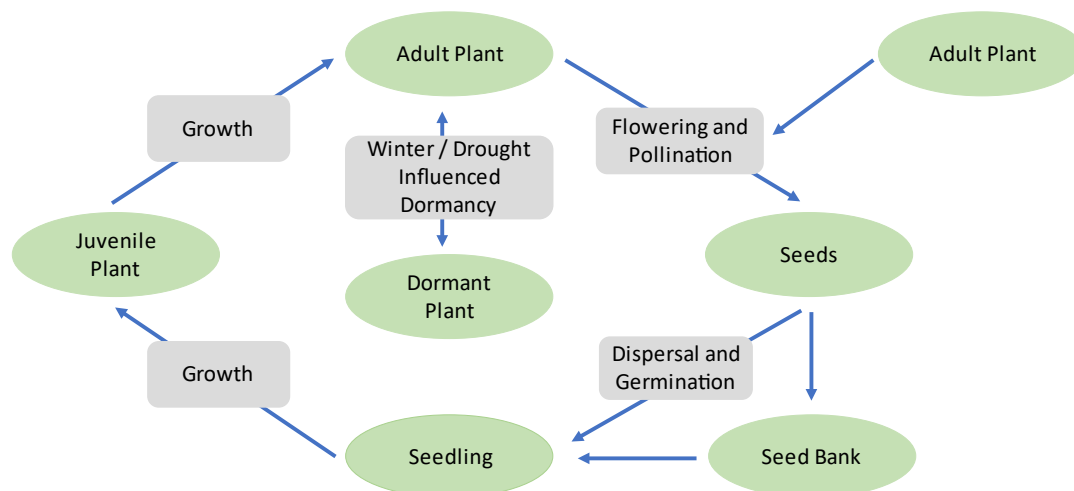


Figure 2-2. Life cycle stages of Venus flytrap: adult (flowering) plant (which may transition to a dormant stage), seeds (which either germinate or become part of the seed bank in the soil), seedling and juvenile plant.



Figure 2-3. Venus flytrap plant in flower showing the flowers elevated well above the trap-like leaves. Photo Credit: The Nature Conservancy

Fruits mature in June and July (Roberts and Oosting 1958, p. 202; Weakley 2020, p. 1055). When the capsule ripens, Venus flytrap seeds are dispersed by gravity, falling onto soil at the base of the parent plants. Some seed distribution may occur by rain splash, rain wash (Roberts and Oosting 1958, p. 202) or during large flood events such hurricanes and tropical storms (M. Kunz, pers comm., 2021). A seed bank develops within the substrate (Bailey and McPherson 2012, p. 106). The seeds can germinate immediately after ripening (Roberts and Oosting 1958, p. 215). New seedlings have been observed in the field in late July and early August and usually occur in protected areas such as the base of mature plants or in *Sphagnum* moss mats (Roberts and Oosting 1958, p. 202). Based on observations in germination trials at the North Carolina Botanical Garden (NCBG), Venus flytrap germination was consistent between seeds with no stratification or those cold stratified for 30, 45 and 60 days. Seeds germinated in both light and dark conditions. These experiments were conducted in a germination chamber at 30°C/20°C and a 12h/12h diurnal cycle. They also found that exposure of seeds to 70°C did not alter germination, but exposure to 100°C resulted in no germination, possibly indicating that heat from a fire could have a detrimental effect on Venus flytrap seeds (M. Kunz, pers. comm., email, Oct. 25, 2021).

2.4 Habitat

Venus flytrap is found in the Cape Fear Arch region of NC and SC which includes portions of the Coastal Plain and Sandhills ecoregions. The Cape Fear River, with its underlying geology, soil types and endemic plants, serves as a corridor between the Outer Coastal Plain and the Sandhills and may have served as a migratory corridor to and from refugia during the most recent glacial cycle (LeBlond 2001, pp 94-96). In the Outer Coastal Plain where it is more common, large patches of Venus flytrap occur in sandy pine savannas and wet pine flatwoods and along their ecotones with pocosins and the sandy rims of Carolina bays. These sites are generally flat with wet or moist soils for much of the year, and some sites have Sphagnum moss carpets (Luken 2005a, p. 581). In the Sandhills region, Venus flytrap is limited to Sandhill seeps which are narrow, moist ecotones between streamhead pocosins (linear, evergreen shrub bogs along small creeks) and pine/scrub oak Sandhill uplands. They are also found along the vegetatively similar ecotones between Sandhill seeps and longleaf pine uplands (Hamon et al. 2021a, p. 7-8; Schafale 2012, pp. 167-171; NatureServe 2021, accessed Sept. 20, 2021; and M. Schafale, pers. comm., email, September 7, 2021).

Wet pine savannas are dominated by longleaf pine trees scattered such that abundant sunlight reaches the ground (Figure 4-4). These habitats often have a highly diverse herbaceous flora that is adapted to frequent fires. Fire (either natural or prescribed) is important to managing the natural habitat for Venus flytrap and other savanna species (Hamon et al. 2021a, p. 8). Only sites that are well managed with prescribed fire are likely to support Venus flytrap over time (M. Schafale, pers. comm., email, September 7, 2021; Gray et al. 2003, p. 213). Venus flytrap is well adapted to fire and can be abundant and a major component of the herbaceous understory where favorable conditions exist. Venus flytrap appears to grow best in areas with little competition from other herbaceous or woody species that might create shade (Bailey and McPherson 2012, p. 102). Plants growing in shade produce smaller leaves more typical of those found on plants in the winter or spring and they also produced fewer flowers (Roberts and Oosting 1958, p. 207, 217). Without regular fire, herbaceous and woody vegetation would likely shade out Venus flytrap populations. More specifically, growing season fires are favored over dormant season burns because they are more effective at reducing woody competition. Growing season fires also mimic naturally occurring fires which are typically started from lightning strikes associated with summer thunderstorms. The longleaf pine ecosystem where Venus flytrap is found has a historical average fire return interval of two to four years (Guyette et al. 2012, p. 330). Venus flytrap plants become dormant following several years without fire and initiate growth in response to increased light availability after a fire (Luken 2005b, p. 682). Over time, shaded plants in fire suppressed conditions will decline and may eventually disappear (Roberts and Oosting 1958, p. 217). Frost (1998, p. 78), called Venus flytrap “one of the most fire-dependent species.” Boyer (1995, p. 24) suggested a one to three-year fire frequency to knock back woody growth and clear grass thatch and leaf litter. Gray et al. (2003, p. 216) suggested a two-year fire return interval to maintain rare species such as Venus flytrap at Fort Bragg Army Base in NC. Louthan et al. (2022, p. 25) found that the optimal fire return interval for Venus flytrap population growth is different than that for any component vital rate and estimates the optimal return interval as 10-12 years; however the authors discuss how much more frequent application of prescribed fire in the landscape is likely needed to accomplish the effective experience of fire in moist Venus flytrap habitats.

Roberts and Oosting (1958, p. 204-205) found that plots that were cleared and burned exhibited greater flowering than plots not burned and Luken (2007, p. 50) documented that fire increased flowering rate in Venus flytrap suggesting that fire stimulated flowering. Hamon et al. (2019, pp. 144-147) did not find any associations between Venus flytrap flower production per individual and time since burn, but did find that the total area occupied by flowering Venus flytrap plants decreased with increasing time since burn.

In addition to Longleaf Pine communities, this species sometimes occurs on roadsides or powerline corridors where they intersect former savannas or other, suitable habitat. While these areas may contain plants, they are not great habitat as they are often altered by rutting and mechanical disturbance and subject to mowing and herbicide application (M. Schafale, pers. comm., email, September 7, 2021).



Figure 2-4. Venus flytrap habitat, longleaf pine savanna at the Green Swamp Preserve owned by The Nature Conservancy, Brunswick County, NC. Photo Credit: Dale Suiter

2.5 Soils

Venus flytrap grows in acid soils that are low in nutrients (Bailey and McPherson 2012, p. 102; Roberts and Oosting 1958, entire). Venus flytrap is commonly found growing on the following soil series: Baymeade (Arenic Hapludults), Blaney (Arenic Hapludults), Foreston (Aquic

Paleudults), Grifton (Typic Orchraqualfs), Johnston (Cumulic Humaquepts), Kureb (Spodic Quartzipsamments), Leon (Aeric Haplaquods), Murville (Typic Haplaquods), Onslow (Spodic Paleudults), Pactolus (Aquic Quartzipsamments), Rains (Typic Paleaquults) and Woodington (Typic Paleaquults). Johnston, Kureb and Murville soils occur on the edges of more suitable soils and are probably inclusions rather than the dominant soil series (NatureServe 2021, accessed Sept. 20, 2021) (M. Schafale, pers. comm., email, September 7, 2021).

2.6 Climate

The climate of southeastern NC and northeastern SC where Venus flytrap populations occur is classified as a humid subtropical climate by the Koppen Trewartha Climate Classification Model which means this area has at least eight months with a mean temperature above 10 °C (50 °F) or higher (Vivid Maps, 2022, accessed February 9, 2022). It is characterized by hot, humid summers and mild winters (Hamon 2021, p. 8). According to the National Weather Service the mean total annual precipitation for Wilmington, NC from 2000-2021 is 59.10 inches (maximum 102.40 inches in 2018, minimum 33.35 inches in 2007) (National Weather Service, 2022, accessed Mar. 31, 2022). While Venus flytrap plants thrive in wet conditions, mature Venus flytrap plants can survive periods of drought by losing their leaves and becoming dormant, surviving as an underground rhizome (Bailey and McPherson 2013, p. 105; Roberts and Oosting 1958, p. 217). This species can also survive prolonged periods of submergence under water which may happen after tropical storm related floods (Roberts and Oosting 1958, p. 217). Traps may remain active underwater (Schnell 1976, p. 21).

Although we have no evidence to indicate the natural range was larger than what we currently know, the climatic conditions of the area where Venus flytrap is found are similar to surrounding areas. The general climate within the species range is not significantly different than the climate 81 km (50 mi) outside its range and therefore is not considered a major influence in the delimitation of the current range of the species (Roberts and Oosting 1958, p. 216).

2.7 Historical and Current Range

Venus flytrap has a historical range within a 161 km (100 mi) of Wilmington, NC (Figure 2-5). Based on North Carolina Natural Heritage Program (NCNHP) data, Venus flytrap has been found in 18 NC counties (Beaufort, Bladen, Brunswick, Carteret, Columbus, Craven, Cumberland, Duplin, Hoke, Jones, Lenoir, Moore, New Hanover, Onslow, Pamlico, Pender, Robeson and Sampson) and three counties in SC (Charleston, Georgetown and Horry).

Currently, the species is considered extant in 11 NC counties (Bladen, Brunswick, Carteret, Columbus, Craven, Cumberland, Hoke, New Hanover, Onslow, Pender and Sampson) and one county in SC (Horry). Historical occurrences occurred in seven additional counties in NC (Beaufort, Duplin, Jones, Lenoir, Moore, Pamlico, and Robeson). In SC, historical occurrences were in Charleston and Georgetown counties (NCNHP 2022, unpublished data; SCNHP 2021, unpublished data; Wichmann 2021, p. 30, B. Wichmann pers. comm., email, Aug. 12, 2021). The counties with historical populations are mostly located around the periphery of the range, suggesting a reduction in the species' range.

Venus flytrap has been introduced in the wild in Florida, New Jersey and other states; however, these are not considered natural populations and they were not considered in this assessment (Evert 1957, entire; Miller 2019, entire; Smith 1972, entire; Weakley 2020, p. 1055).

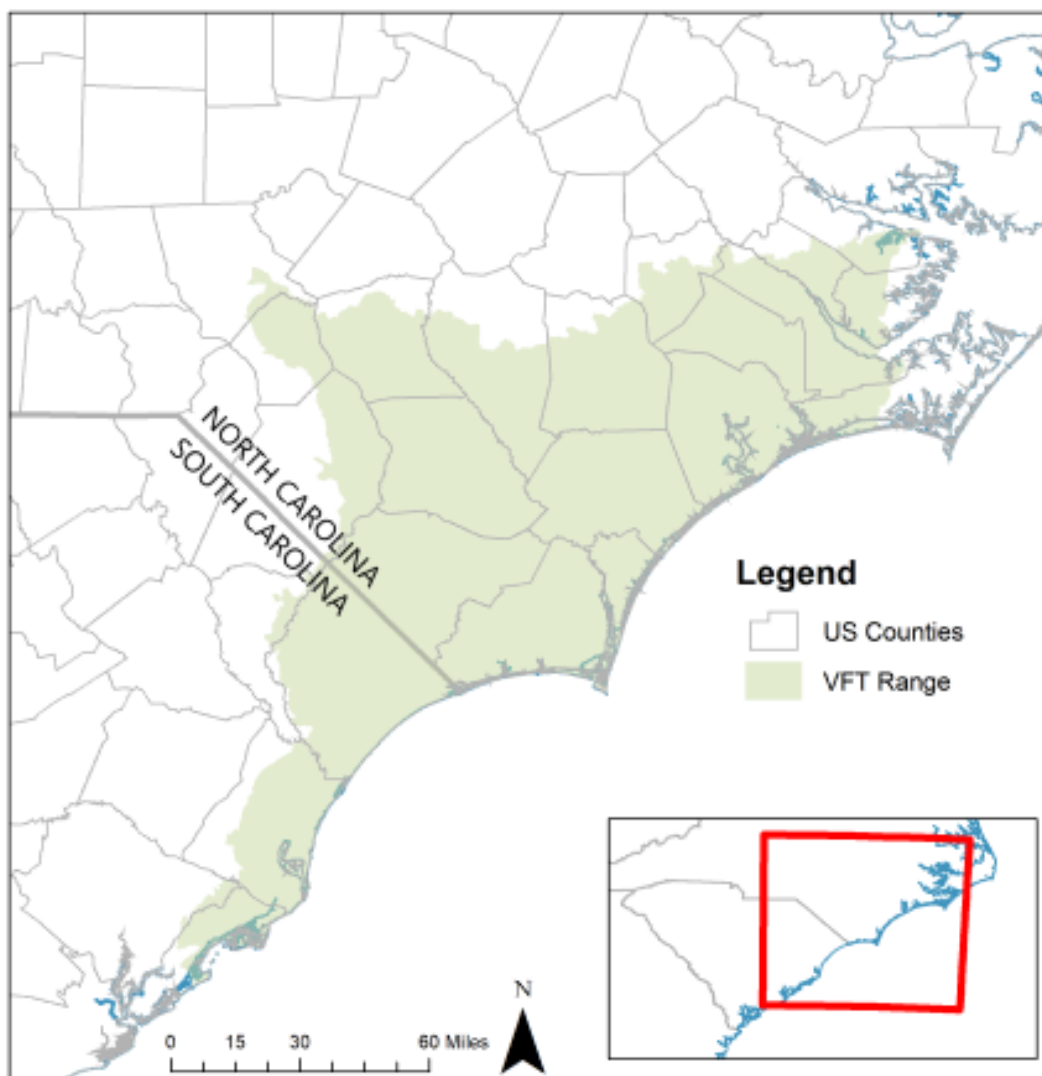


Figure 2-5. Map of Venus flytrap range.

2.8 Individual Needs

In this section, we describe and evaluate the individual needs of Venus flytrap in terms of the resource needs and/or the circumstances that are necessary to complete each stage of the life cycle (Figure 2-2), including reproductive adults, seeds, seedlings, and juvenile plants.

The availability of abundant sunlight and moisture is important for all life stages of Venus flytrap. In the Coastal Plain, this species grows primarily in wet pine savannas and wet pine flatwoods and their ecotones with pocosins, sometimes associated with sphagnum. In the Sandhills, it grows in ecotones between pocosins and seeps and longleaf pine uplands (Hamon et al. 2021a, p. 7-8, NatureServe 2021, accessed Sept. 20, 2021). Venus flytrap plants are often,

but not always associated with sphagnum moss carpets (Hamon et al. 2021a, p. 8; Luken 2005a, p. 581). Venus flytrap plants require wet or moist acidic soils that are low in nutrients (Bailey and McPherson 2012, p. 102; Roberts and Oosting 1958, entire).

Abundant sunlight is important for Venus flytrap to complete its life cycle as light suppression reduces flowering and subsequently seed production in Venus flytrap. Vegetative or asexual reproduction occurs from buds that grow from short rhizomes (Hamon et al. 2021a, p. 22). Natural or prescribed fires are critical to Venus flytrap survival as they reduce competition of woody and herbaceous vegetation and keep the forest floor where Venus flytrap plants grow open to sunlight. Frost (1998, p. 78), noted that Venus flytrap plants in research plots at the Green Swamp (NC) die out when not burned at least every three years. He called Venus flytrap “one of the most fire-dependent species.” According to Hamon (2021, p. 11) many of the largest and densest populations of Venus flytrap are found in habitat that is burned frequently (at least every three years) (Hamon et al. 2021a, entire). Luken (2007, p. 50) demonstrated that the highest flowering and seedling establishment occurred soon after prescribed fire. Venus flytrap sites with less canopy cover and more exposure to sunlight support more robust populations.

Water is necessary for plant growth. Hydrogen molecules from water are required for photosynthesis which converts sunlight, carbon dioxide and water into carbohydrates. Water is carried through the vascular tissue of plants and is released through open stomata (openings on the leaves) in a process called transpiration which assists with cooling plants. As water transpires through the leaves, it carries minerals from the soil that are essential for healthy plant growth (InTeGrate 2022, accessed May 5, 2022). As mentioned in section 2.4 (Habitat), Venus flytrap occurs in wet longleaf pine savannas and associated habitats that contain abundant moisture. This species can tolerate short periods of drought, but it is not tolerant of extended dry conditions.

Venus flytrap has an interesting relationship with arthropods. This carnivorous plant is well known for its ability to trap and digest arthropods, while some insects also play an important role in their reproduction. Venus flytrap reproduces by both sexual and asexual reproduction, the former, also involving insects. Sexual reproduction occurs when Venus flytrap plants produce flowers. The flowers are self-compatible, but insects are required for pollination and seed production (Hamon 2022, p. 84-89). Flowers are visited by a generalist suite of pollinators; however, the primary pollinator is a sweat bee (*Augochlorella gratiosa*) while the longhorned beetle (*Typocerus sinuatus*) and the checkered beetle (*Trichodes apivorus*) are also considered important pollinators (Hamon et al. 2021a, p. 7; Youngsteadt et al. 2018, p. 3-4).

Venus flytrap plants trap insects, spiders and other arthropods using its snap trap shaped leaves. Despite the name “flytrap,” studies indicate that spiders, ants and beetles make up the largest groups of arthropods found in the traps of Venus flytrap plants (Youngsteadt et al. 2018, p. 2; Ellison and Gotelli 2009, p. 27). Youngsteadt et al. (2018, p. 3-4) collected prey from 212 traps and determined that 40% were spiders, 26% were Hymenoptera (mostly ants) and 11% were Coleoptera (beetles). Ellison and Gotelli (2009, p. 27) reported similar results in their survey of other trap studies. Researchers also determined that there was very little overlap between prey and pollinators, an indication that Venus flytrap rarely traps its pollinators (Youngsteadt et al. 2018, entire). Spatial separation may play a role in partitioning pollinators and prey as flowers

are elevated well above the traps and most flower visitors fly, while most prey are not able to fly (Youngsteadt et al. 2018, p. 6). Schulze et al. (2012, p. 1313-1317) deep sequenced cDNA from the traps to identify the proteins secreted during digestion. The results suggest that the plants digestive system evolved from defense-related processes. Hamon (2022, p. 84) conducted prey supplementation experiments in 2020 which showed that plants that received supplemental prey produced nearly twice as many flowers as those that received only naturally available prey. This result suggests that prey availability in the field may limit flytrap sexual reproduction.

2.9 Population Needs

At the population level, resource needs include the key needs of individuals mentioned above (abundant light, abundant moisture, moist acidic soils, arthropods, and fire) as well as sustainable population size and connectivity between populations. The NCNHP rank specifications for this species indicate that populations with 1,000 or more plants have good viability (Hamon 2021 p. 19). Small population size can increase the risk of genetic drift (changes in allele frequency/disappearance of particular genes) and inbreeding depression (mating of related individuals) (Ellstrand and Elam 1993, pp. 218-219). Small population size and isolated populations can change pollinator behavior by causing less visitation due to the limited resources available to pollinators. Small, isolated populations of rare plant species often receive less pollinator visitation in comparison with larger or more widespread plant species (Ellstrand and Elam 1993, p. 227).

Lastly, populations need suitable habitat within the population area and between populations to create connectivity. Habitat and population connectivity provides higher pollinator visitation rates to flowers in comparison with fragmented habitats or populations (Kearns and Inouye 1997, p. 299). Connected populations can have up to three times higher visitation rates in comparison with isolated populations. Overall, the large Venus flytrap populations on large protected sites in comparison with the small, isolated populations often on private land highlight the importance of population size and connectivity in relation to viability.

Reduced seed set serves as an indicator of pollinator loss (Kearns and Inouye 1997, p. 298). Hamon (2022, pp. 47 and 87) found pollen supplementation to increase seed set from 0% to 27% and noted that it is common for a species' pollen limitation to differ among sites and years.

2.10 Species' Needs

Regarding the species' needs and viability, there must be adequate redundancy (suitable number of resilient populations, distribution of resilient populations, and connectivity between populations to allow the species to withstand catastrophic events) and representation (suitable genetic and environmental diversity to allow the species to adapt to changing environmental conditions). Redundancy is measured by numbers of populations in medium to high resiliency condition and connectivity (either natural or anthropogenic-influenced) among those populations to allow populations to "rescue" each other after catastrophic events. Representation is a measure of genetic diversity and adaptive capacity to changing environmental conditions.

CHAPTER 3: CURRENT CONDITION

3.1 Delineating Populations

In this document, we use two terms to refer to groupings of Venus flytrap plants: population (or Principal Element Occurrences (EOs)) and subpopulation. Following NatureServe guidelines for defining populations, a generic distance of 2 km (1.2 mi) was used to denote separate populations of Venus flytrap. Data analysts buffered the records by 2 km (1.2 mi) and denoted a single population as occurring if the buffer overlapped. When occurrences within 2 km (1.2 mi) were disjunct from one another for more than 1 km (0.6 mi) due to unsuitable habitat, the analysts used a 1 km (0.6 mi) separation distance rule to separate populations. A population of Venus flytrap may vary widely in size, ranging from a single cluster of a few individuals to tens of thousands of individuals distributed over several hectares. A subpopulation refers to geographically distinct groups of individuals within a population. The subpopulation designation is somewhat subjective but is broadly a method of distinguishing parts of a population for the purposes of data management and conservation planning (Hamon et al. 2021a, p. 14; NatureServe 2021, entire).

3.2 Methods for Estimating Current Condition

To assess the biological status of the Venus flytrap across its range, we used the best available information including peer-reviewed scientific literature, a recent status survey, survey data provided by state natural heritage programs and other agencies, unpublished information from species experts, and information in our files. Detailed surveys of Venus flytrap populations were previously conducted in 1991-1992 (Boyer 1995, entire), 2002 (Shew 2002, entire), 2017-2018 (Kunz 2018, entire) and 2019-2021 (Hamon et al. 2021a, entire) and contributed greatly to the NCNHP database and, ultimately, this document. We defined Venus flytrap populations using known occurrence data provided by NCNHP and SCHTP (NCNHP 2022, unpublished data; SCNHP 2021, unpublished data). According to the SSA framework, we assessed the species' current condition in the context of the 3Rs—resiliency, redundancy, and representation. We determined resiliency for each population and then evaluated resiliency, redundancy, and representation at the range-wide scale.

3.3 Current Population Resiliency

For the purpose of this assessment, we defined resiliency as the ability of Venus flytrap to sustain populations in pine savanna ecosystem over time. Each population of Venus flytrap needs to be able to withstand, or be resilient to, stochastic events or disturbances (e.g., drought, flooding, fluctuations in seed viability, etc.). To have high resiliency, these populations need to have an adequate number of individuals, cover a large enough area (multiple occurrences within a population) and have connectivity within a population so that a localized event does not eliminate a population.

To assess resiliency, we considered a combination of factors including population size (number of individual plants), the number of subpopulations within each population, the area occupied by a population (acreage), and management regime. A summary of the criteria used to measure each factor is provided in Table 3-1. For each Venus flytrap population, scores were applied to each criterion based on high, medium, and low condition. We determined resiliency for each

population and then evaluated resiliency, redundancy, and representation at the range-wide scale. A summary of the resiliency of each population is provided in Appendix A.

3.3.1 Population Size

Population size or the number of individual plants making up a population is an important indicator of resiliency. Venus flytrap rank specifications developed by the NCNHP and adopted by the SCHTP assign viability ranks based on population size (number of individual plants). They have identified populations with more than 2,000 plants (A-ranked) as having excellent viability and populations with 1,000 to 2,000 plants (B-ranked) with good viability. Populations with 500 to 1,000 (C-ranked) plants are considered to have fair viability and those with 500 plants or less (D-ranked) have poor viability (Hamon et al. 2021a, p. 19).

To analyze current condition, we considered populations with 10,000 or more plants to have high resiliency. Since eight Venus flytrap populations have over 10,000 plants and three of those have more than 100,000 plants, we determined 10,000 plants to be a reasonable threshold for highly resilient populations. We considered populations with 1,000 to 10,000 plants to have medium resiliency. We considered populations with less than 1,000 plants as having low resiliency (Table 3-1).

3.3.2 Number of Subpopulations

Venus flytrap flowers are self-compatible, but fertilization requires insects to carry pollen to the stigma. Large populations consisting of multiple subpopulations are more likely to receive greater pollinator visitation (Ellstrand and Elam 1993, p. 227). Therefore, populations with greater than five subpopulations are considered highly resilient. Populations with two to five subpopulations have medium resiliency and those consisting of only one EO with no subpopulations are believed to have low resiliency (Table 3-1).

3.3.3 Management

As mentioned in section 2.4 (Habitat), Venus flytrap occurs in wet pine savannas and wet flatwoods with sparse mature longleaf pine trees and few shrubs and understory trees. Fire, historically caused by summer lightning strikes and to a lesser degree indigenous burning practices, is essential to maintaining these open conditions. While adult longleaf pine trees are resistant to fire, many hardwood species are not and are killed or set back by fire. Many herbaceous species of these habitats are also fire adapted whereby the tops of the plants can be periodically burned off allowing more sunlight to reach Venus flytrap plants on the ground. Therefore, growing season prescribed fires are an important management tool to maintain conditions that are necessary for the long-term viability / resiliency of this species. In some situations, mechanical clearing has been used as an alternative to fire in order to reduce fuel loads and maintain open conditions for the species (Kunz 2018, entire).

For the purposes of this analysis, we queried land managers for each Venus flytrap population about their management practices, primarily in the form of prescribed or natural fires. Then, we scored each population based on the level of management, fires that occur and at what interval. Populations that are actively managed for savanna conditions and burned an average of 1 to 4 years (on average) were ranked as highly resilient. Those that are generally managed for savanna conditions with an average fire return interval of 5 to 8 years were considered to have

medium resiliency. Populations with fires every 9 or more years, or with no fire history or an unknown management or fire history were considered to have low resiliency in this category (Table 3-1).

3.3.4 Area Occupied

The aerial extent of a population is a sign of resiliency, with larger populations offering a greater amount of habitat. Larger populations are often buffered from external stressors and are often easier to manage with prescribed fire. We considered populations over 400 acres in size to be highly resilient, populations with 200 to 400 acres to have medium resiliency, and populations less than 200 acres have low resiliency (Table 3-1).

3.3.5 Current Population Resiliency Summary

Resiliency describes the ability of a population to withstand environmental or demographic stochastic disturbance. To determine current resiliency of the 74 extant Venus flytrap populations, we assigned scores for each metric (Table 3-1) from 1 to 3, with 1 being low, 2 being medium and 3 being high for each of the four metrics: population size, number of subpopulations, management, and size of area occupied. Scores were weighted equally and added up to determine an overall resiliency score for each population. Overall scores could range from 4 to 12 and were evenly divided into three categories: high resiliency equates to scores between 10 and 12; medium resiliency is scores between 7 and 9; low resiliency is scores between 4 and 6. Details of these scores are provided in Appendix A. We did not complete resiliency scores for Venus flytrap populations ranked as failed to find (F), historical (H), or extirpated (X) because it is likely that these populations no longer exist and do not contribute to the current resiliency of the species.

Table 3-1. Metrics used to assess and determine the current condition and population resilience of Venus flytrap (number of plants, number of subpopulations, size and management) and scores assigned to high, medium and low categories

Score	Number of plants	Number of subpopulations	Size (Acreage)	Management
High = 3	10,000+	>5	>400	Managed with prescribed fire; majority of Venus flytrap habitat burned within a 1-4 year return interval.
Medium = 2	1,000-10,000	2-5	200-400	Managed with prescribed fire; majority of Venus flytrap habitat burned within a 5-8 year return interval.
Low = 1	<1,000	1	<200	Managed with prescribed fire or not; majority of Venus flytrap habitat burned with a 9+ year return interval OR fire history unknown OR not managed at all.

Using the resiliency scores calculated for the 74 extant Venus flytrap populations, we determined that eight populations are considered highly resilient, ten populations considered to have medium resiliency, and 56 populations have low resiliency (Table 3-2). Based on this analysis, the most resilient populations are those with a large number of individual plants, made up of multiple subpopulations, and are managed with frequent fire. Across its range, 21 populations (28% of total) occur on protected areas managed for conservation, 24 populations occur on military land

or lands with mixed ownership (32% of total), and 29 populations (39% of total) occur on private lands with no protection designation (Table 3-3). It is worth noting that the three largest populations contain an estimated 584,700 plants, which is approximately 66% of the total number of estimated plants (880,300) (Hamon et al. 2021a, p. 21). These three populations occur on lands owned by The Nature Conservancy, NC Wildlife Resources Commission, and Camp Lejeune Marine Corps Base. It is anticipated that these populations will continue to be managed into the future. The populations on The Nature Conservancy and NC Wildlife Resources Commission lands are considered protected, however populations on Camp Lejeune Marine Corps Base may be impacted by future training activities, and are partially protected.

Table 3-2. Summary of Venus flytrap populations in each resiliency category.

Resiliency category	Number of populations	Percent of total number of populations	Percent of total number of extant populations
High	8	6	11
Medium	10	7	14
Low	56	40	76
None*	66	47	0
Total	140	100	100

* This includes populations ranked Failed to Find, Historical, or Extirpated by the Natural Heritage Programs. Definitions of ranks can be found in NatureServe (2008 pp. 3-4). Note: percentages may not add up to 100 based on rounding.

Table 3-3. Summary of Venus flytrap populations located in protected lands, mixed ownership/military lands, and non-protected lands.

Resiliency Category	Land Designation		
	<i>Protected Area</i>	<i>Mixed Ownership/Military</i>	<i>No Protection</i>
<i>High</i>	5	3	0
<i>Medium</i>	5	5	0
<i>Low</i>	11	16	29
TOTAL	21 (28%)	24 (32%)	29 (39%)

Resiliency is associated with stochastic risk and the population's ability to withstand stochastic events. We use the following terminology to calibrate and standardize language regarding risk (Table 3-4):

Table 3-4. Presumed probability of persistence of current condition categories for Venus flytrap.

Overall condition based on resiliency	Risk to species viability	Persistence over 30 Years	Probability of Persistence
High	Low	Very likely	90-100 %
Medium	Medium	Likely	30-90%
Low	High	Unlikely	0-30%
Extirpated	N/A	Not at all likely	0%

Therefore, the 18 populations that are in medium or high resiliency condition have greater than 30% probability of persistence over 30 years, with eight populations (or 11% of the extant populations) with a very likely, or greater than 90% probability of persistence over that timeframe. These 18 resilient populations are likely to withstand stochastic disturbances, thus they are able to sustain populations through the natural range of favorable and unfavorable conditions. Fifty-six (76%) of the populations are currently in low resiliency condition and have a less than 30% probability of persistence in the future.

3.4 Current Representation

Representation is the ability of a species to adapt to new environments. It reflects a species' adaptive capacity to respond to changing environmental conditions over time and can be characterized by the breadth of genetic and ecological diversity within and among populations. We evaluated representation by examining the breadth of ecological diversity found within Venus flytrap and its ability to disperse and colonize new areas.

For Venus flytrap, we do not have information on the genetic diversity within and among all of the populations across the species' range. In the absence of species-specific genetic and ecological diversity information, representation can be assessed based on the extent and variability of habitat characteristics across the geographical range. Venus flytrap occurs in different ecoregions across its geographic range that could influence its genetic makeup and adaptive capacity to respond to environmental changes. Ecoregions are a system of classification based on physiography, where areas with similar characteristics of land formation, dominant soil and vegetation types, climate, air and sea currents, and distribution of flora and fauna are grouped into a single ecoregion (Bailey 1983, entire). Ecoregions have been used to reflect broad areas within which local adaptations and genetic coadaptation have likely occurred. As mentioned in the habitat section (2.4), the plant communities where Venus flytrap occurs in the Coastal Plain are different from the plant communities where it is found in the Sandhills. Therefore, we used ecoregions as a proxy for factors likely to influence the adaptive capacity of Venus flytrap across the landscape. We mapped populations across the three ecoregions in which it occurs (Outer Coastal Plain, Inner Coastal Plain, and Sandhills) in the southeastern U.S. We used the U.S. Environmental Protection Agency's (USEPA) Level IV Ecoregions spatial map to delineate Venus flytrap representation units (USEPA 2013, unpaginated, accessed Apr. 6, 2022) (Figure 3-1). We estimated representation as the number of medium to highly resilient populations within each of the ecoregions (Figure 3-1, Table 3-5).

While Venus flytrap populations are known to occur in three ecoregions of NC and SC, we do not know whether the species was historically distributed evenly throughout these ecoregions, but we suspect it was more widespread in the Outer Coastal Plain, as it is now. All eight highly resilient populations occur in the Outer Coastal Plain (Table 3-5). Eight populations with medium resiliency occur in the Outer Coastal Plain and two are in the Sandhills. Populations with low resiliency occur throughout all three ecoregions with 48 in the Outer Coastal Plain, one in the Inner Coastal Plain and seven in the Sandhills. In addition, 66 populations are considered extirpated, including 54 in the Outer Coastal Plain, nine in the Inner Coastal Plain and three in the Sandhills (Table 3-5). The current number of low resiliency and extirpated populations in the

Inner Coastal Plain indicate a slight reduction in representation, primarily because these very small populations do not contribute much to overall viability of the species.

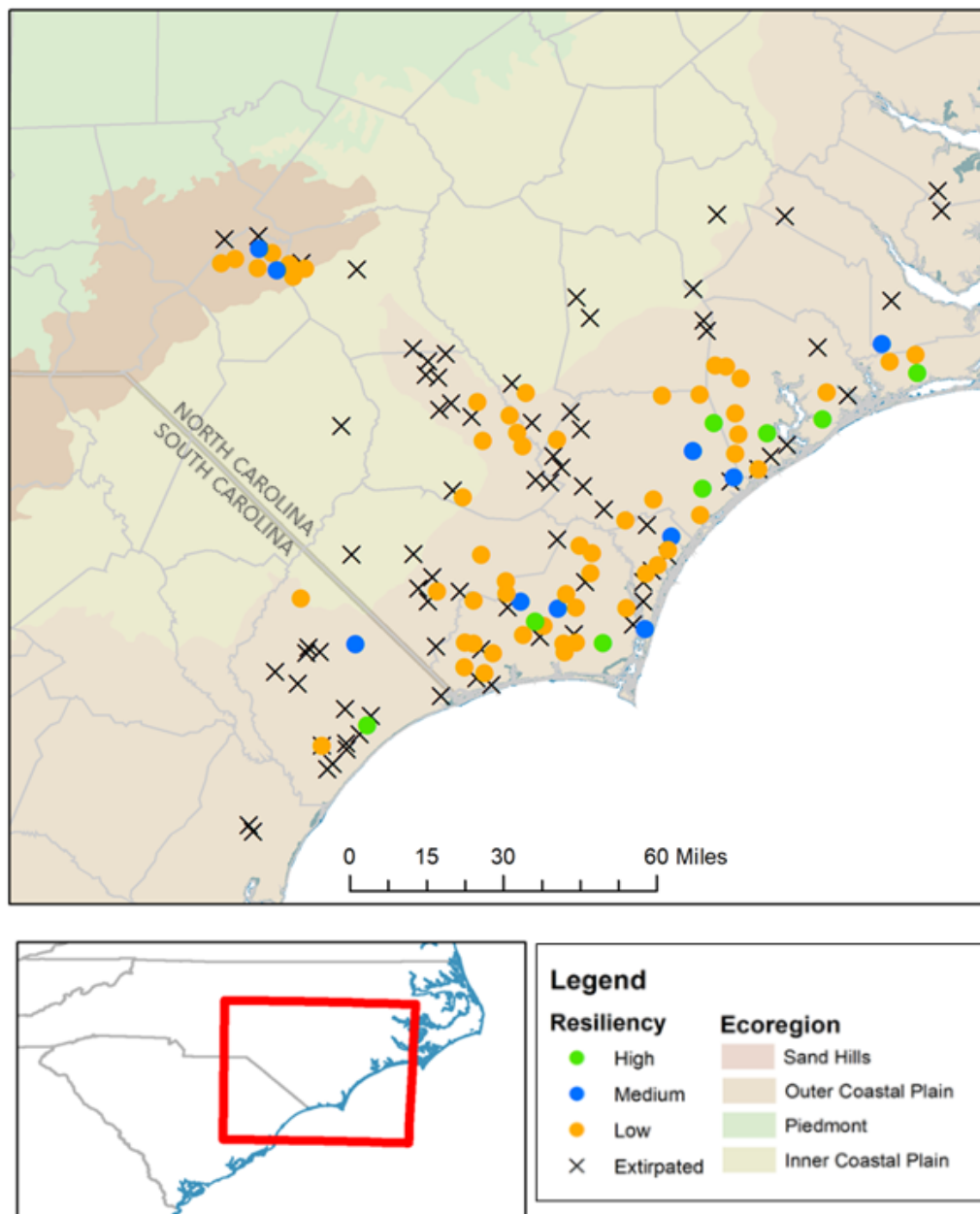


Figure 3-1. Map of Venus flytrap current population resiliency across ecoregions.

Table 3-5. Summary of the number of Venus flytrap populations by resiliency in each ecoregion.

Resiliency	Outer Coastal Plain	Inner Coastal Plain	Sandhills	Totals
High	8	0	0	8
Medium	8	0	2	10
Low	48	1	7	56
None (extirpated)	54	9	3	66
Totals	118	10	12	140

As previously mentioned, representation is also a function of adaptive capacity. Adaptive capacity is the ability of a species to cope with or adjust to changes, including climatic changes, and is a component of vulnerability or extinction risk (Thurman et al. 2020, p. 520). We used an attribute-based framework (Figure 3-2; Thurman et al. 2020, entire) to evaluate the adaptive capacity of Venus flytrap.



Figure 3-2. The adaptive capacity “wheel,” depicting 36 individual attributes organized by ecological complexes (or themes). Twelve core attributes are particularly important to analyze, and are highlighted in blue (Thurman et al., 2020, entire).

DeWan et al. (2010, p. 15) present a graphic describing how life history traits influence species vulnerability in response to climate change (Figure 3-3):

Species least at risk	Species most at risk
• Physiological tolerance to broad range of factors such as temperatures, water availability and fire • High degree of phenotypic plasticity • High degree of genetic variability • Short generation times (rapid life cycles) and short time to sexual maturity • High fecundity • ‘Generalist’ requirements for food, nesting sites, etc. • Good dispersal capability • Broad geographic ranges	• Narrow range of physiological tolerance to factors such as temperature, water availability and fire • Low genetic variability • Long generation times and long time to sexual maturity • Specialized requirements for other species (e.g. for a disperser, prey species, pollinator or photosynthetic symbiont) or for a particular habitat that may itself be restricted (e.g. a particular soil type) • Poor dispersers • Narrow geographic ranges

Figure 3-3. Climate vulnerability based on species traits (DeWan et al., 2010, p. 15). Based on the availability of data and expert knowledge for Venus flytrap, we used 12 “core” attributes, which collectively span the seven themes from Figure 3-2 and provide a comprehensive means of assessing adaptive capacity. These attributes are also addressed in Figure 3-3 above from DeWan et al. (2010, entire). We used a low-moderately low-moderate-moderately high-high scale for a qualitative assessment of each of the attributes (Thurman et al., 2020, WebTables 1 and 2) (Figure 3-4; Appendix B).

Theme	Core Attribute	Adaptive Capacity Level
Distribution	Extent of Occurrence	Moderately High
	Habitat Specialization	Low
	Commensalism with Humans	Moderately Low
Evolutionary Potential	Genetic Diversity	Unknown
	Population Size	High
Movement	Dispersal Distance	Low
Abiotic Niche	Climatic Niche Breadth	Moderate
	Physiological Tolerances	Moderate
Ecological Role	Diet Breadth	High
Demography	Reproductive Phenology	Moderate
Life History	Life Span	Moderately Low
	Fecundity	Low

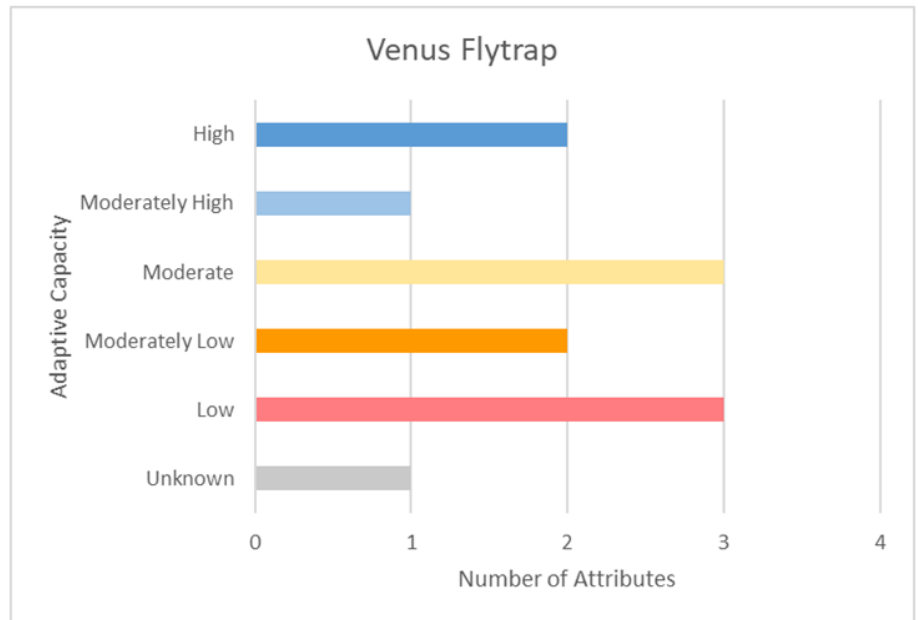


Figure 3-4. Adaptive capacity summary for Venus flytrap. The table indicates adaptive capacity level for each of 12 core attributes and graph shows the number of attributes within each of the criteria bins (ranging from low to high and including unknown attributes). See Appendix B for more details about the attributes analyzed.

Currently, Venus flytrap exhibits varying levels of adaptive capacity depending on the attribute under consideration, with high levels of adaptive capacity attributable to its population size and diet breadth, moderate-high levels attributable to its extent of occurrence, moderate levels attributable to physiological tolerances and reproductive phenology, moderately low levels attributable to commensalism with humans and life span and low levels of capacity based on habitat specialization, dispersal distance, climatic niche breadth and fecundity. Genetic diversity is unknown. The flytrap’s occupancy within a narrow range of the Coastal Plain, including a large number of extirpated populations in the Outer Coastal Plain and Inner Coastal Plain indicate reduced overall representation. This ultimately limits aspects of its adaptive capacity, as it is unlikely to move across the landscape outside of its required habitat type to other suitable conditions, thus it is unable to “shift in space” (Thurman et al. 2020, p. 522). Thus, Venus flytrap is subject to anthropogenic and climatic stressors that require a “persist in place” strategy, which it currently exhibits ability to withstand, at least in some portions of its range.

Each ecoregion where Venus flytrap is found provides different geology, topography, climatic variability, soils, and other characteristics that drive biotic and abiotic environmental diversity

and adaptive pressures, and the species' persistence in these areas demonstrates increased adaptive capacity.

3.5 Current Redundancy

Redundancy is the ability of a species to withstand catastrophes or stochastic events and is characterized by having multiple, resilient populations across the species range which increase the species' ability to persist after a catastrophic event. 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 Venus flytrap, redundancy is characterized by having multiple resilient populations within the three ecoregions or representational units and across the species' entire geographic range. Venus flytrap has a relatively small range with all populations occurring within a 160 km (100 mi.) semicircle north, west and south of Wilmington, NC. This area occupies approximately 28,490 square km (11,000 square mi), an area about the size of the state of Massachusetts. To describe redundancy, we assessed the number of extant and extirpated Venus flytrap populations within defined ecoregions (Outer Coastal Plain, Inner Coastal Plain, and Sandhills) and across the species' entire range. Of 140 known populations (extant and extirpated), 118 (84%) are located in the Outer Coastal Plain, 10 (7%) are in the Inner Coastal Plain and 12 (9%) in the Sandhills (Table 3-4). This is an indication that this species was likely never widespread in the Inner Coastal Plain and Sandhills ecoregions.

A total of 74 populations are considered extant and 66 are considered extirpated. Considering the 74 extant populations, we looked at the number of high, medium, and low resiliency populations within each ecoregion (Table 3-4). Of the 64 extant populations in the Outer Coastal Plain, eight populations (12.5%) have high resiliency, 8 (12.5%) have medium resiliency, and 48 (75%) populations have low resiliency. There are 16 high to medium resilient populations (30%) equally distributed across six counties in the Outer Coastal Plain. All of the highly resilient and many of the medium resilient populations occur on large, protected, and managed lands such as The Nature Conservancy preserves, State-owned game lands and preserves, National Forests and military lands such as Camp Lejeune Marine Corps Base and Marine Ocean Terminal at Sunny Point that receive moderate protection. Only one extant population remains in the Inner Coastal Plain and is considered to have low resiliency. Of the nine extant populations in the Sandhills, seven (78%) have low resiliency and two (22%) have medium resiliency. These Sandhills populations all occur at Fort Bragg Army Base where they are considered moderately protected. Since Fort Bragg could change the land use of the areas where these populations occur, the long-term protection and management of these populations is uncertain.

Within the narrow range of Venus flytrap, the species has a broad distribution, with 74 of the 140 (53%) known populations extant. It is important to note that for most extirpated populations, we do not know the size of those populations at their peak. They could have been large populations at one time or they could have been small isolated populations with just a few plants, however, we are not aware of any large populations that have been lost in the last 30 years. The Outer Coastal Plain has a large number of populations overall, with 18 high and medium resiliency populations distributed throughout six counties. The eight highly resilient sites (11% of the known extant sites) all occur in this ecoregion and they contain 97% of the total plants in existence today. The greatest reduction in redundancy has been observed in the Inner Coastal

Plain where nine of 10 (90%) known populations are now considered extirpated. In the Sandhills, nine medium and low resiliency populations occur on Ft. Bragg Army Base (Table 3-4). Despite the loss of 47% of the known populations, Venus flytrap retains redundancy overall. With multiple medium and highly resilient populations in the Outer Coastal Plain ecoregion and several medium to low resilient populations in the Sandhills, this species should be able to withstand catastrophic events.

3.6 Summary of Current Condition

Of 140 Venus flytrap populations, 74 are considered extant and 66 are considered extirpated. Eight populations (11%) are highly resilient, 10 populations (14%) have medium resiliency, and 56 (76%) have low resiliency. The most resilient populations occur in the Outer Coastal Plain (all eight highly resilient and 8 of the 10 populations with medium resiliency). Venus flytrap was likely never widespread through the Inner Coastal Plain and Sandhills like it is in the Outer Coastal Plain. Approximately two-thirds of all known plants (584,700 of 880,300) occur at the three largest populations. These three populations occur on a preserve owned by The Nature Conservancy, a state-owned game land, and a military base. The nature preserve and game land are protected from future development and managed with prescribed fire and are expected to remain highly resilient. The third largest Venus flytrap population occurs on a military base where regular fire has maintained this population; however, management of the military base could change so the long-term protection of this population is less certain. While 66 populations are considered extirpated, we do not know the original population sizes nor do we know the historical resiliency of those populations that no longer exist. With regards to representation, the fact that Venus flytrap persists in different plant communities within the Outer and Inner Coastal Plain and the Sandhills with different environmental conditions between the ecoregions demonstrates moderate adaptive capacity. The large number of low resiliency and extirpated populations indicate reduced representation across ecoregions. Overall, Venus flytrap has multiple medium and highly resilient populations in the Outer Coastal Plain and some medium and low resilient populations in the Sandhills, thus enabling the species to withstand catastrophic events.

CHAPTER 4: FACTORS INFLUENCING SPECIES' VIABILITY

4.1 Background

In order to determine the greatest threats to Venus flytrap, we reviewed Natural Heritage Program element occurrence records and queried land managers and biologists familiar with Venus flytrap populations. We organized threats into common themes. The greatest threats to Venus flytrap are associated with various actions that modify or destroy habitat such as fire suppression. Other threats that modify or destroy habitat include right-of-way maintenance and conversion to agriculture (including silviculture) and residential and commercial development. Other stressors that could have a negative effect on the species include poaching and small population size nonnative invasive species, herbivory, and climate change. Likewise, there are many ongoing positive actions that benefit Venus flytrap such as habitat protection and management, state laws that protect Venus flytrap, international recognition, horticultural availability of ethically grown plants and grass roots efforts to work with landowners and raise awareness about Venus flytrap conservation.

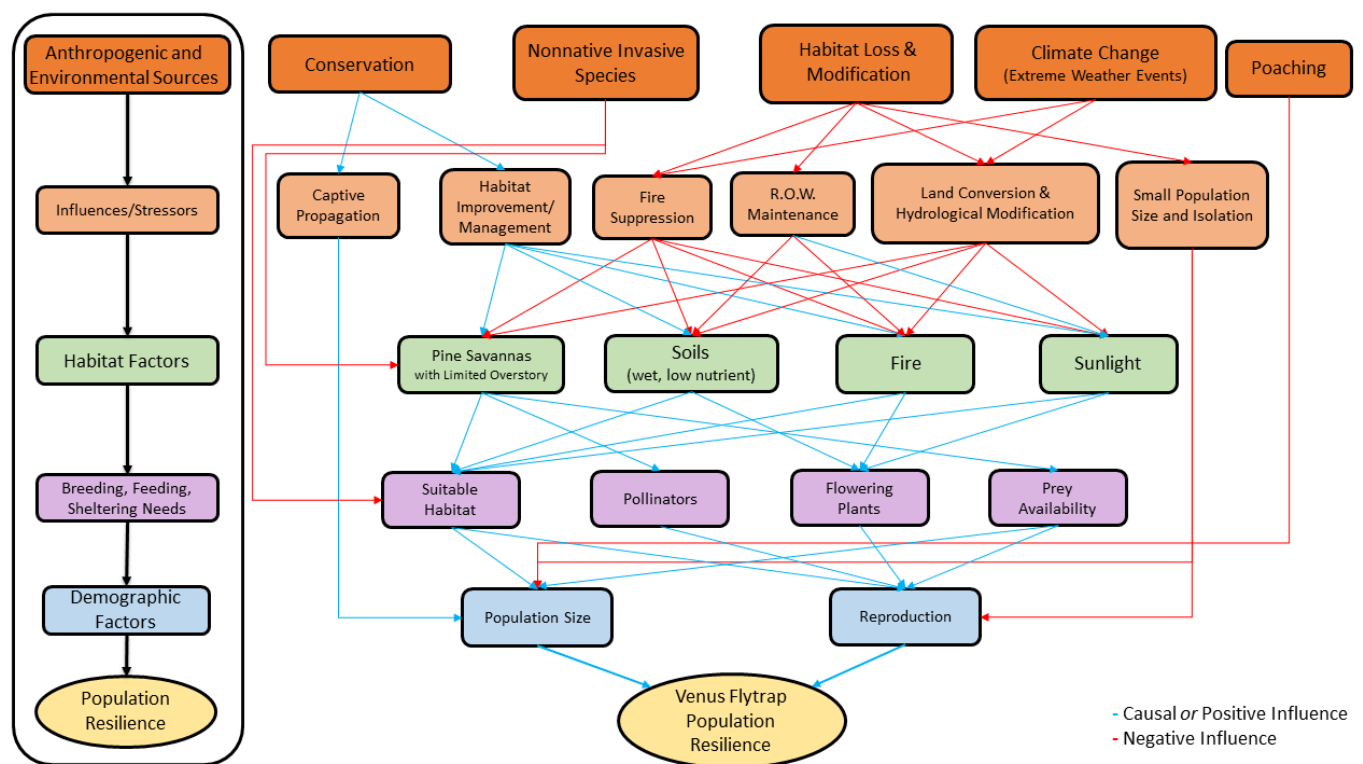


Figure 4-1. Venus flytrap influence diagram showing relationships between factors and species' viability.

4.2 Habitat Loss and Modification

We do not know the range of Venus flytrap prior to European settlement in the Carolinas, but we have no evidence that it was significantly more widespread than its currently known range. As mentioned in section 2.7 (Historical and Current Range) above, Venus flytrap has been reported from 18 counties in NC and three counties in SC. Currently, it is considered extant in 11 NC counties and one county in SC (NCNHP 2022, unpublished data; SCNHP 2021, unpublished data; Wichmann 2021, p. 30; B. Wichmann, pers. comm., email, Aug. 12, 2021). The counties where the species is considered historical are at the northern, southern and western edges of its known range, an indication that the range of extant populations is shrinking. Historically, longleaf pine occupied 93 million acres (37 million hectares) across the southeastern Atlantic coastal plain and piedmont. Agriculture, open livestock grazing, turpentine production and the elimination of wildfires have reduced the amount of landscape with longleaf pine to less than 3% of what it once was (Frost 1993, pp. 17, 37).

The loss of Venus flytrap habitat may result from fire suppression and land conversion to agriculture, silviculture, residential and commercial development and associated fragmentation, right-of-way (ROW) management and other factors.

4.2.1 Fire Suppression

Natural fires are a regular occurrence in the southeastern coastal plain. The warm, humid climate of the southeast combined with killing frosts and occasional droughts create a condition where there is plenty of volatile fuels to ignite in the presence of a lightning strikes (Finch *et al.* 2012, p. 105). The southeastern coastal plain has one of the highest lightning frequencies in North America (Finch *et al.* 2012, p. 105).

Historical accounts suggest that the indigenous people of the southeast Coastal Plain conducted wide-ranging burns on an annual basis to clear the forest undergrowth (Earley 2006, p. 73-84; Edwards *et al.* 2013, p. 357.). Native Americans reportedly had an annual custom of “setting the woods on fire many miles in extent” for hunting (Catesby 1731, p. 13). After the displacement of indigenous people from the land, anthropogenic prescribed fires in the Southeast were still largely practiced on an annual rotation as many farmers used fire as a tool to “green up” the woodlands for cattle and other livestock (Frost 1993, p. 34).

The shift from free roaming cattle to enclosed livestock due to the “stock laws” likely resulted in more agriculture production and less livestock grazing. As, farmers shifted from cattle ranching to agriculture, the need to “green up” the woodlands for cattle decreased and fire suppression likely increased as a result of this shift across the Southeast (Frost 1993, p. 28). By 1920-1950, suppression of wildfires and anthropogenic fires due to modern fire laws resulted in a major shift causing most longleaf pine savanna and flatwood ecosystems to be overgrown with dense second-growth forests (Frost 1993, p. 38).

Both natural and prescribed fires are beneficial to the longleaf pine ecosystem where Venus flytrap occurs. This ecosystem is adapted to regular fires. Venus flytrap plants require open, sunny conditions to survive. This species is intolerant of dense shade. Photosynthesis, which is necessary for their survival, requires sunlight, water and carbon dioxide to produce energy (stored in carbohydrate molecules). Fire is an important factor in maintaining favorable growing

conditions and without it, populations eventually die out (Roberts and Oosting 1958, p. 217; Hamon et al. 2021, p. 10). Shaded conditions negatively affect flowering and seed production in Venus flytrap (Roberts and Oosting 1958, pp. 216-217). Fires set back herbaceous plants and suppress or kill deciduous shrubs and trees, thereby reducing competition. Fire also promotes seedling establishment and flowering (Roberts and Oosting 1958, pp. 204, 207, Luken 2007, p. 50; Hamon et al. 2021, p. 10). Longleaf pine is resistant to fire and the trees are often widely spaced, creating an open canopy. The combination of an open canopy with few deciduous trees and shrubs and herbaceous plants that are suppressed by regular fires allows more sunlight to reach the ground where low growing Venus flytraps occur. Fire also facilitates seedling establishment and stimulates flowering (Luken 2007, p. 50).

Frost (1998, p. 78) calls Venus flytrap one of the most fire dependent species, noting that it begins to die out when fire-return intervals become longer than three years. Fire suppression is considered one of the main threats to Venus flytrap as it disrupts natural fire cycles which often results in increased shading and competition from woody plants, eventually causing the decline of herbaceous plant species. The longleaf pine forests where Venus flytrap plants are found has a historical average fire return interval of one to four years (Frost 1998, p. 77; Guyette et al. 2012, p. 330). Venus flytrap plants are able to persist in a state of dormancy following a period of fire suppression and initiate growth in response to increased light availability (Luken 2012, p. 682); however, over time, shaded plants decline, causing populations to disappear (Roberts and Oosting 1958, p. 217). For example, J. Luken (pers. comm., email, Nov. 9, 2021) has observed that large gallberry (*Ilex coriacea*) forms dense, thick stands which shade out Venus flytrap plants in fire suppressed populations at Lewis Ocean Bay Heritage Preserve in SC.

In addition to the lack of fire, fire suppression techniques such as plowing and bulldozing can be detrimental to herbaceous species. Many Venus flytrap populations occur in plow lines that serve as fire breaks but are subject to destruction when those fire breaks are maintained (plowed to expose mineral soil). Approximately 1,000 Venus flytrap plants were destroyed when a power line easement in Onslow County, NC was plowed up to serve as a fire break for the Juniper Creek Fire in June 2011 (NCNHP 2022, unpublished data). There have been two incidents in the Croatan National Forest, where fire plow lines to contain wildfires directly impacted Venus flytrap plants (A. Walker, pers. comm., email, May 12, 2022).

4.2.2 Land Conversion

Other types of habitat loss such as the conversion of land from longleaf pine savannas and associated Venus flytrap habitat to agricultural lands, silviculture (tree farming), or residential and commercial development are more immediate and permanent.

Clearing land for conversion to agriculture and silviculture is destructive to Venus flytrap populations and often has permanent impacts on the landscape. The physical act of clear cutting destroys Venus flytrap plants. The habitat is further altered to make it suitable for planting additional trees or agricultural crops. Much of land within the range of Venus flytrap has been converted to loblolly pine production. This may involve cutting existing longleaf pine, scraping the ground, ditching and draining which changes the hydrology and makes the soil too dry for moisture-dependent Venus flytrap. Clear cutting also allows the sun to quickly dry out the soil. Conversion to silviculture includes site preparation and herbicide application. A silviculture

practice called bedding involves converting flat, poorly drained land into a series of parallel rows and furrows which alters the hydrology. These actions, along with fast rotation cycles (less than 25 years), results in stands with reduced species diversity and unsuitable habitat for Venus flytrap. The Newport Timber Project in the Croatan National Forest is proposed to occur in a known Venus flytrap population. Staff will use non-mechanical thinning techniques to avoid Venus flytrap population (A. Walker, pers. comm., email, May 12, 2022.).

Another type of land conversion is development. Residential and commercial development can have direct and indirect negative impacts on Venus flytrap populations. Development typically converts natural areas from forests to residential and commercial spaces for living, shopping and recreation. This type of land conversion is typically irreversible. Development also leads to fragmentation of natural areas which can negatively affect native species, even if not impacted directly. Fragmentation is a serious threat to biodiversity. It reduces plants to isolated populations which face a higher risk of extinction (Matthies et al. 2004, p. 481). Plants in small, isolated patches may receive fewer visits from pollinators which can reduce fecundity due to insufficient pollination (Matthies et al. 2004, p. 482).

The human population within the range of Venus flytrap (southeastern NC and northeastern SC) is growing rapidly. Some of the most robust Venus flytrap populations occur in Brunswick, Carteret, New Hanover, Onslow, and Pender counties in NC and Horry County, SC. According to the NC office of State Budget and Management, all of these NC counties had positive population changes ranging from 1.7% to 28% (Table 4-1) (NC Office of State Budget and Management 2022). Of all NC counties, Brunswick County, where two of the largest Venus flytrap populations occur, had the second largest increase (28%) during that 10-year period. Home to the largest Venus flytrap population in SC, the Horry County population increased 36.9% during that 10-year period (SC Revenue and Fiscal Affairs Office 2019).

Table 4-1. Population change in counties from 2010 to 2020 (NC Office of State Budget and Management 2022; SC Revenue and Fiscal Affairs Office 2019).

County	2010 Population	2020 Population	Population Change (numeric)	Population Change (percent)
Brunswick, NC	107,429	137,530	30,101	28
Carteret, NC	66,463	67,571	1,108	1.7
New Hanover, NC	202,683	225,730	23,047	11.4
Onslow, NC	177,801	204,842	27,041	15.2
Pender, NC	52,195	60,325	8,130	15.6
Horry, SC	270,257	370,075	99,818	36.9

Population increases contribute to urban sprawl in the form of residential and commercial development. The construction of residential neighborhoods, golf courses and commercial development may result in the direct loss of Venus flytrap habitat or fragmentation of existing populations. Development also increases the wildland-urban interface which complicates the management of natural areas with prescribed fire. Such development often precludes the ability to use fire as a management tool at nearby protected populations because of the threat of fires escaping the natural area or their proximity to Smoke Sensitive Areas (e.g. schools, hospitals,

homes, poultry houses, etc.) (NC Forest Service 2020, p. 7). For example, the patchy network of conservation lands at the NC Plant Conservation Program's Boiling Springs Lakes Plant Conservation Preserve in Brunswick County, NC makes it difficult to manage some parcels with prescribed fire (L. Starke, pers. comm., email, Nov. 19, 2021). Similarly, the Lewis Ocean Bay Heritage Preserve in Horry County, SC is difficult to manage with prescribed fire as more and more residential subdivisions and a hospital are built around the perimeter of the preserve (J. Fowler, pers. comm., email, Feb. 23, 2022).

In 2021, the National Aeronautics and Space Administration (NASA) DEVELOP program partnered with the NCBG, the University of North Carolina Herbarium, and the NCNHP to support Venus flytrap conservation. The team developed models based on species presence data and environmental variables using the Software for Assisted Habitat Modeling (SAHM) to create a 2021 habitat suitability map for Venus flytrap. To predict areas at high risk of development, the team produced a 2050 land-use change map using TerrSet Land Change Modeler (LCM) (Figure 4-2). The results indicate that there may be areas of future conflict between predicted habitat for flytraps and forecasted future development. Many areas of suitable habitat were concentrated along the coast where development is predicted to occur, potentially placing populations in those areas at risk of extirpation. Overlaying suitable habitat with forecasted land change also identified suitable habitats with minimal risk of development, which may serve as potential Venus flytrap habitat (NASA DEVELOP 2021, entire).

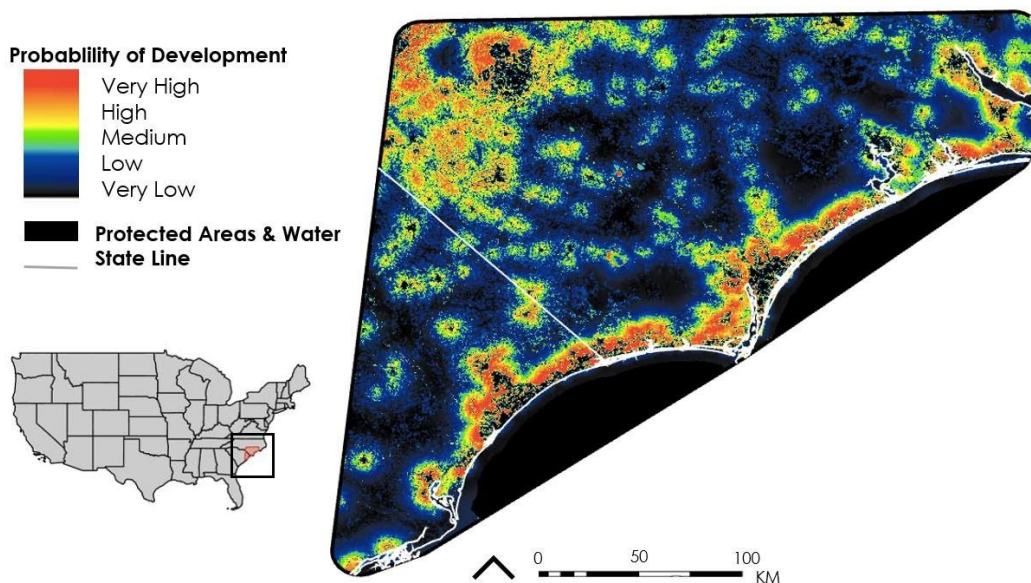


Figure 4-2. Probability of land to transition to developed land cover by 2050 (NASA DEVELOP 2021).

Habitat loss through land use change is a primary threat to Venus flytrap, and this study identified a number of areas within species' range with high potential to transition to developed land cover by 2050. Forecasted development, like suitable habitat, is concentrated along the coast of NC and SC. Based on comparisons between the habitat suitability model and LCM, 55.6% of the areas predicted to have highly suitable habitat for Venus flytrap also have high (greater than 50%) potential to become developed by 2050. Locations with known Venus flytrap

populations and high potential to transition to developed land cover by 2050 represent areas where Venus flytrap's long-term survival may be threatened. These areas of conflict could/should be prioritized for protection or seed banking to conserve the genetic diversity of populations at high risk of development (NASA DEVELOP 2021, entire).

4.2.3 Roadside and Utility Right-Of-Way Management

Venus flytrap populations sometimes occur on roadsides and utility line ROW where roads and utility lines intersect suitable habitat for this species. These populations are vulnerable to road maintenance, road widening projects, herbicide application and mowing. Road maintenance and widening projects can destroy habitat where plants occur. Herbicides, which suppress plant growth, are often used to manage vegetation along road shoulders and in utility ROW. Herbicide damage can be temporary or permanent depending on the type of herbicide used and the rate of application. Dormant season (winter) mowing is generally not problematic for disturbance-dependent species, as it helps reduce competition and maintain sites in an open condition. However, it is important that dormant season mowing be conducted when soils are not too wet to avoid creating ruts which can kill small plants and disrupt the microtopography. Mowing that occurs during the growing season before plants produce mature seeds is harmful to the population because it eliminates seed production/reproductive potential for that year. In general, populations that occur in roadside and utility line ROW are extremely vulnerable to poor management actions.

In some cases, it is possible to manage lands adjacent to ROW populations to create suitable habitat for the species out of harm's way. This can be done by cutting trees or opening up the habitat so seeds find suitable places to germinate outside of the ROW. This is done with the hope that the species will gradually occupy habitat away from the ROW; however, adjacent, protected land does not always exist.

4.3 Poaching and Overcollection

Another threat to Venus flytrap is poaching plants from the wild. Poaching is defined as taking plants without permission of the landowner. For many years, Venus flytrap plants have been the subject of illegal collection from the wild. Initially this was done so they plants could be sold at roadside markets and more widescale in the horticulture trade. In more recent years, we believe that poaching may also involve the pharmaceutical industry (McManus 2014, p. 4).

Until recently, trespass laws and the NC Plant Protection and Conservation Act were the main way to address Venus flytrap poaching (see section 4.8.3, State Laws, below). In 2014, the NC Legislature passed a law making it a felony to take Venus flytrap plants from someone else's land without written permission of the landowner. In 2019, the NC Department of Agriculture and Consumer Services (NCDACS) and the NC Wildlife Resources Commission (NCWRC) entered into a Memorandum of Understanding whereby the NCWRC will fully enforce the NC Plant Protection and Conservation Act and its accompanying regulations (L. Starke, pers. comm., email, Nov. 19, 2021). This state law is also enforced by local and county police.

People charged with poaching Venus flytrap are often also charged with other crimes such as the possession of drugs. Due to multiple charges, the poaching charges often get thrown out or dismissed when they go to court. Poachers openly tell the law enforcement officers that the

punishment for the crime is so minor that there is no incentive to not poach. In other words, they make more money poaching and selling plants than they pay in fines. NCWRC Law Enforcement does not keep a record of arrests or convictions related to plant poaching and are not able to search arrest records for particular crimes, but officers still see evidence of poaching since the felony law was passed in 2014 (B. Dean, pers. comm., email, Mar. 23, 2022).

The Service is only aware of three poaching events caught by law enforcement officers since the felony law was passed in 2014. A person convicted of poaching 970 plants from Holly Shelter Game Land in January 2015 was sentenced to six to 17 months in prison (WBTW News 13 2016, entire, accessed May 19, 2022). In November 2015, two men were charged with taking 1,025 Venus flytrap plants and two pitcher plants from Orton Plantation in Brunswick County (WETC News 6 2015, entire, accessed May 19, 2022). The most recent arrest was in Mar. 2019, when a Brunswick County man was arrested for taking over 216 plants from state game lands (Smajstrla 2019, entire, accessed May 19, 2022).

At the Croatan National Forest, Venus flytrap poaching is considered to be on a small scale and occurs at a few easily accessed locations. It is not considered a serious threat at this time (A. Walker, pers. comm. email, May 12, 2022).

The NC Chapter of The Nature Conservancy investigated the market for Venus flytrap plants and conducted an evaluation into the factors that drive poaching of Venus flytrap. McManus (2014, entire) looked at the supply chain, horticultural market, medicinal market and international marketplace to learn more about the reasons for poaching and who or what industries support poaching. She determined that the global market for Venus flytrap is far greater than the available plants in nature and that tissue culture is the most common method of propagating this species. She also observed that no companies (medicinal or horticultural) advertise or promote “wild-sourced” plants (McManus 2014, p. 2-4).

Regarding the concern for overcollection of wild plants, Venus flytrap has been the subject of various types of academic research for many years, some of which involves the collection parts of plants or entire plants from natural populations. Current research projects focus on genetics, demography, response to drought, nutrient input, prey availability and pollination ecology. These studies involve the collection of leaves, flowers, traps and seeds for laboratory and field experiments or the collection of voucher specimens for herbaria. NCBG biologists collected Venus flytrap leaf samples for genetics research and seeds that are stored in their seed bank for future research and restoration efforts. NCBG follows the Center for Plant Conservation guidelines for seed collection to minimize impacts to populations. At Duke University researchers are investigating the species’ response to drought, nutrient input and prey availability involve natural occurring plants or plants grown from seeds that were collected from natural populations. NC State University pollination ecology experiments involve wild plants in the field and some germination experiments using wild collected seeds. All of these research projects were permitted by the NC Plant Conservation Program. Prior to issuance of their research permits, each project was evaluated by a team of botanists and it was determined that the level of collection was unlikely to pose any potential threat of overutilization for the species. Poaching is probably most harmful to small populations which have fewer plants. When a larger

percentage of total plants are removed from a population, it is harder for that population to recover to the number of plants present before the poaching event.

In summary, Venus flytrap poaching still occurs, but it appears to happen locally and on a small scale. While there appears to be much talk about poaching among Venus flytrap enthusiasts, conservationist and the media, the actual number of reported incidents is relatively small. While some large poaching events are not insignificant, overall poaching impacts probably pale in comparison to lack of proper fire management development and other land use changes mentioned above in section 4.2 (Habitat Loss and Modification).

4.4 Small Population Size and Isolation

As mentioned in section 2.9 (Population Needs) above, small population size can result in loss of genetic diversity due to inbreeding and genetic drift (changes in allele frequency/disappearance of particular genes) and inbreeding depression (mating of related individuals) (Ellstrand and Elam 1993, pp. 218-219). Small population size and isolated populations can change pollinator behavior by causing less visitation due to the limited resources available to pollinators. Small, isolated populations of rare plant species often receive less pollinator visitation in comparison with larger or more widespread plant species (Ellstrand and Elam 1993, p. 227). Small populations can also be vulnerable to stochastic processes (Matthies et al., 2004, pp. 481, 485-486). In their study of short-lived plants, Matthies et al. (2004, p. 485) determined that very small populations faced a considerable risk of extinction over a 10-year period while the risk for populations greater than 1,000 individuals was very small.

Narrow endemic species whose populations exhibit a high degree of isolation are extremely susceptible to extinction from both random and nonrandom catastrophic natural or human-caused events. Species that are restricted to geographically limited areas are inherently more vulnerable to extinction than widespread species because of the increased risk of genetic bottlenecks, random demographic fluctuations, climate change, stochastic events, and localized catastrophes such as hurricanes and disease outbreaks (Mangel and Tier 1994, p. 607; Pimm et al. 1988, p. 757). These problems are further magnified when populations are few and restricted to a very small geographic area, and when the number of individuals is very small. Populations with these characteristics face an increased likelihood of stochastic extinction due to changes in demography, the environment, genetics, or other factors (Gilpin and Soule 1986, pp. 24-34). Small, isolated populations often exhibit reduced levels of genetic variability, which diminishes the species' capacity to adapt and respond to environmental changes, thereby decreasing the probability of long-term persistence (e.g., Barrett and Kohn 1991, p. 4; Newman and Pilson 1997, p. 361). Very small plant populations may experience reduced reproductive vigor due to ineffective pollination or inbreeding depression. Isolated individuals have difficulty achieving natural pollen exchange, which limits the production of viable seed. The problems associated with small population size and vulnerability to random demographic fluctuations or natural catastrophes are further magnified by synergistic interactions with other threats, such as those discussed above.

4.5 Nonnative Invasive Species

Nonnative invasive plants compete with native plants for space, light, water, and nutrients, and modify native plant communities. Nonnative invasive animals may eat and/or disturb native

vegetation. In general, longleaf pine savannas and their associated communities do not have many invasive species. Nonnative invasive species are not considered a significant threat to Venus flytrap at this time; however, land managers at Venus flytrap populations identified three species that may negatively affect this species in the future.

According to K. Bradley (pers. comm., email, Nov. 8, 2021), Torpedograss (*Panicum repens*) is expanding along roads and utility ROW at the Lewis Ocean Bay Heritage Preserve. This species could be a threat to any ROW populations of Venus flytrap on the preserve. Torpedograss plants were treated with herbicide in 2020 and 2021.

Cogongrass (*Imperata cylindrica*) was first introduced accidentally to Louisiana in 1912 (as packing material) and intentionally to Florida in the 1930s (as forage) (USDA National Invasive Species Information Center, accessed May 18, 2022). This federal noxious weed is considered one of the top 10 invasive weeds in the world and is now found as far west as Texas and north to Tennessee and NC (NCDACS undated a, accessed May 18, 2022). It spreads by seeds and rhizomes and competes for resources with native species. Cogongrass burns very hot which makes wildfires and controlled burns very dangerous and can also damage young tree stands. Cogongrass has been found at five locations in NC. These locations are in two counties where Venus flytrap occurs (Pender and Sampson). All five sites have been treated with herbicides and are being monitored by the NCDACS (J. Driscoll, pers. comm., email, Dec. 3, 2021). Managers of Venus flytrap populations search for this species on their properties. At the time of this assessment, there are no known populations of cogongrass co-occurring with Venus flytrap populations.

Feral hogs (*Sus scrofa*) 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 (Barrios-Garcia and Ballari, 2012, pp. 2284-2293). Feral hogs have been documented at several Venus flytrap populations but do not appear to be causing significant damage at this time. Feral hogs are present on the Croatan National Forest, but generally are not known to occur in areas that contain Venus flytrap populations (A. Walker, pers. comm., email, May 12, 2022). Likewise, hogs are present at Holly Shelter Game Land, but occur mostly on adjacent property or in the vicinity of food plots (J. Street, pers. comm., email, Nov. 9, 2021). They are not found in areas where Venus flytrap occurs. Feral hogs are also present, but rare at Lewis Ocean Bay Heritage Preserve (K. Bradley, pers. comm., email, Nov. 8, 2021).

4.6 Herbivory

White-tailed deer (*Odocoileus virginianus*) have been documented browsing on the flowers and fruiting heads of Venus flytrap, but deer herbivory on the leaves has not been reported.

Venus flytrap is one of the primary hosts for the extremely rare Venus flytrap cutworm moth (*Hemipachnobia subporyphryea*) and is therefore critical to its survival. Based on the best available information at this time, we do not believe that browsing or herbivory are causing population-level effects to Venus flytrap (Hamon et al. 2021a, p. 22; 2021b, entire).

4.7 Climate Change-Associated Factors

Despite the recognition of potential climate effects on ecosystem processes, there is uncertainty about what the climate future for the Southeast will be and how ecosystems and species in this region will respond. However, it has been noted that our scientific understanding of the climate system strongly supports the conclusion that large changes in NC's climate, "much larger than at any time in the state's history," are very likely by the end of the century under both the low (RCP 4.5) and high (RCP 8.5) scenarios (Kunkel et al. 2020, p. 5). The greatest threat from climate change may come from synergistic effects. That is, factors associated with a changing climate may act as risk multipliers by increasing the risk and severity of more imminent threats (Figure 4-3; Elliot et al. 2014, p. 67 -68). As a result, impacts from land use change might be exacerbated under even a mild to moderate climate future.

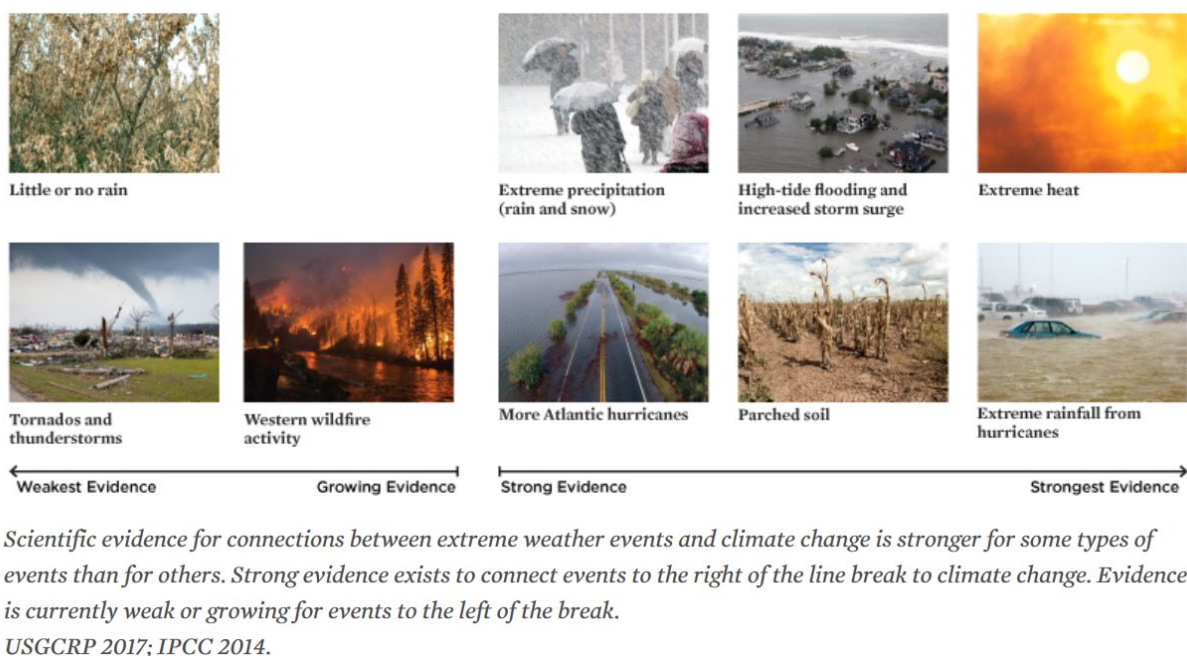


Figure 4-3. Connection between extreme weather events and climate change (credit: Union of Concerned Scientists 2018, entire).

Regardless of climate future, the following systematic changes are expected to be realized to varying degrees in the southeastern U.S., including southeastern NC and northeastern SC (Figure 4-3) (North Carolina Interagency Leadership Team, NCILT 2012, p.27; Intergovernmental Panel on Climate Change, IPCC 2013, p.7; UNC Communications 2019, entire, accessed May 25, 2022):

- More frequent drought
- More extreme heat (resulting in increases in air and water temperatures, see Fig 4-4 below)
- Increased heavy precipitation events (e.g., flooding)
- More intense storms (e.g., frequency of major hurricanes increases)
- Increased fire and fire severity

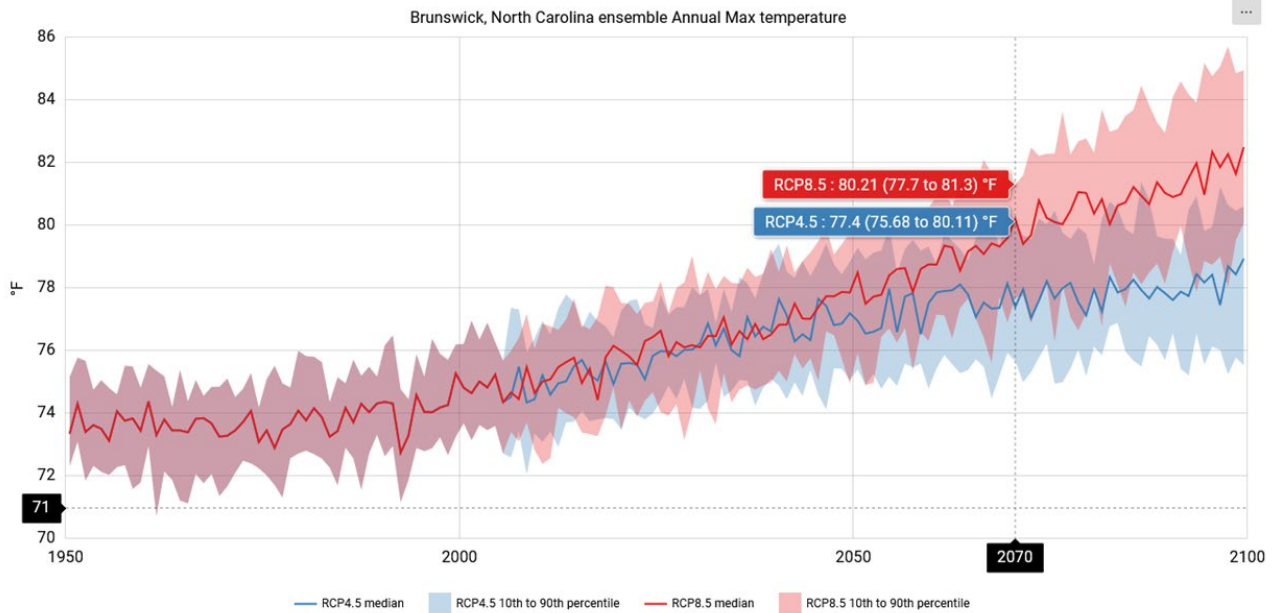


Figure 4-4 Future predictions of extreme heat, or annual max temperature, in Brunswick County, NC (credit: USGS National Climate Change Viewer, <https://www.usgs.gov/tools/national-climate-change-viewer-nccv>)

According to Roberts and Oosting (1958, p. 215) mature Venus flytrap plants can withstand desiccation over short or even extensive periods of time by going into a dormant stage, but seedlings cannot become established in areas where soil drought is common. Louthan et al. (2022, p. 22-27) suggest that flytrap population growth rate could increase under future climate conditions, and that they may benefit from a slightly longer fire return interval, and that their sensitivity to fire return interval may change.

4.8 Conservation Efforts

Venus flytrap has been the subject of much attention and conservation for many years. As previously mentioned, there are several nature preserves dedicated to the conservation of Venus flytrap and associated species. Several state laws protect Venus flytrap from poaching and the horticulture trade produces and sells responsibly grown plants that were not taken from wild populations.

4.8.1 Habitat Improvement, Management, and Protection

Suitable habitat for Venus flytrap is found on State-owned lands, privately owned nature preserves, National Forests, Department of Defense lands, and other conservation areas across the species' range (Table 4-2). Many of these landowners implement beneficial land management practices (e.g., prescribed burning, mowing, mechanical removal of woody vegetation) to maintain the structure and function of wet pine savannas where Venus flytrap occurs by mimicking natural disturbance regimes (Gilliam and Platt 2006, p. 7). Removing woody vegetation encroachment reduces vegetative competition thereby increasing the availability of water, nutrients, and light which are all important to the growth and reproduction of Venus flytrap. At present, five of the highly resilient Venus flytrap populations occur on protected lands. Conservation lands owned by the US Forest Service, State

agencies and private nature preserves are expected to remain protected and managed for conservation purposes in the near future, which would eliminate the risk of direct habitat loss due to urbanization in these areas. Three Department of Defense (DOD) military bases are home to high and medium resilient populations. Their lands are managed with fire to reduce fuel loads; however, land use needs can change and these populations could be negatively affected in the future, therefore, we do not consider them to have the same level of protection as other state and federal lands.

Table 4-2. Protected lands that provide suitable habitat for extant Venus flytrap populations (NCNHP 2022, entire; SCHTP 2021, entire).

State	Owner/Manager	Property
North Carolina	USDA Forest Service	Croatan National Forest
	Department of Defense	Camp Lejeune Fort Bragg Military Ocean Terminal at Sunny Point
	NC Wildlife Resources Commission	Angola Bay Game Land Holly Shelter Game Land Juniper Creek Game Land
	NC Plant Conservation Program	Boiling Springs Lakes Preserve
	NC State Parks	Carolina Beach Lake Waccamaw Sandy Run Savannas Singletary Lake
	The Nature Conservancy	Green Swamp McLean Savanna Myrtle Head Savanna The Neck/Maple Hill Old Dock Savanna
South Carolina	Heritage Trust Program	Cartwheel Bay Lewis Ocean Bay
	Horry County Conservation Foundation	McDowell Preserve

4.8.2 Integrated Natural Resources Management Plans

The Sikes Act requires most military installations within the United States to develop and implement comprehensive plans for natural resource conservation and management (e.g., fish and wildlife, forestry, land management, outdoor recreation) on each installation. This conservation plan, known as an Integrated Natural Resource Management Plans (INRMP), focuses on ecosystem-based management with a goal of managing the natural resources to meet stewardship requirements while supporting, and even enhancing, military operations.

Military installations prepare INRMPs in cooperation with the Service and state fish and wildlife agencies, ensuring appropriate consideration of fish, wildlife, and their habitat needs. This collaborative approach to natural resource conservation directly benefits the Service's ability to enhance and conserve fish, wildlife and plants, as well as their habitats. Due to successful natural

resource conservation and management on installations, landscapes can be conserved and enhanced, providing the benefits of healthy ecosystems to wildlife and human communities, while still being used to support military operations and training.

The INRMPs for Camp Lejeune Marine Corps Base, Fort Bragg and Military Ocean Terminal at Sunny Point (MOTSU) list Venus flytrap as Species at Risk (SAR), Federal Species of Concern (FSC) and priority species, respectively and emphasize the importance of protecting and managing this rare species (Camp Lejeune 2015, p. 4-92-95; MOTSU 2018, p. III-1; Ft. Bragg 2018, p. 3). The MOTSU INRMP mentions that the Forest Management Plan will ensure the conservation of natural communities that will benefit Venus flytrap (and other rare species) (MOTSU 2018, p. III-1). The Fort Bragg INRMP commits to using ecosystem management practices to restore and manage natural communities and improve habitat conditions for rare species (Fort Bragg 2018, p. 3).

4.8.3 State Laws

There are currently four NC laws that are related to Venus flytrap. North Carolina General Statute §145-22, adopted in 2005, designated this species as the official carnivorous plant of the State of North Carolina. This law is simply a designation and does not provide any protections to the species (NC General Assembly 2005, entire).

North Carolina General Statute §14-129 prohibits the taking of certain species of wild plants from the land of another. Specifically, it states that no person, firm or corporation shall dig up, pull up or take from the land of another or from any public domain, the whole or any part of any Venus flytrap or various other species without permission of the landowner. Any person convicted of violating the provisions of this section shall be guilty of a Class 3 misdemeanor only punished by a fine of not less than ten dollars (\$10.00) nor more than fifty dollars (\$50.00) for each offense. The provisions of this section do not apply in Carteret and Pender counties, two counties where Venus flytrap is known to occur (NC Code General Statutes 2005, entire). The full statute is included in Appendix C.

Venus flytrap is currently listed as State Threatened by the NC Department of Agriculture and Consumer Services and is protected by the North Carolina Plant Conservation and Protection Act (North Carolina Code Article 19B, section 106202.12) (Wichmann 2021, pp. 2, 30). The threatened designation is defined as any native or once-native resident species of plant which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range, or one that is designated as a Threatened species pursuant to the Endangered Species Act. This law provides limited protection of Venus flytrap from unauthorized collection (uproot, dig, take or otherwise disturb or remove for any purpose from the land of another without written permission from the owner) and trade (sell, barter, trade, exchange, export, etc.). It is also unlawful to buy more than 50 Venus flytrap plants for the purpose of resale or trade unless fully compliant with applicable regulations. However, the statute does not protect the species or its habitat from destruction in conjunction with development projects or otherwise legal activities. Any person convicted of violating this Article, or any rule of the Board adopted pursuant to this Article shall be guilty of a Class 2 misdemeanor. Each illegal movement or distribution of a protected plant shall constitute a separate violation. This law authorizes the NCPCP to establish nature preserves for protected

species and their habitats. NC Department of Agriculture, Plant Industry – Plant Protection Section – Plant Conservation Program, undated, entire). The Plant Protection and Conservation Act is provided in Appendix C.

In June 2014, the North Carolina General Assembly passed House Bill 1059 which makes it a felony to take Venus flytrap plants or seeds from the land of another. Any person convicted of taking Venus flytrap plants or seeds from another person's land or from public domain without written permission of the landowner or the owner's authorized agent is guilty of a Class H felony (NC Gen Stat § 14-129.3 (2014)). The complete bill is in Appendix C.

South Carolina Code of Laws 16-11-590 (General Bill H*2953), amended on May 19, 1980, makes it unlawful to “collect, cut, break or otherwise destroy Venus's Flytrap plants or any part on public property or on private property without the owner's consent.” Anyone violating this law is guilty of a misdemeanor and if convicted, may be fined \$10 to \$200 per offense and may be imprisoned not more than 30 days. The law also protects sea oats (*Uniola latifolia*) (Justia US Law undated, entire).

4.8.4 Convention on International Trade in Endangered Species of Wild Fauna and Flora

Venus flytrap is listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), an international agreement between governments to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Because the trade in wild animals and plants crosses international borders, the effort to regulate them requires international cooperation to safeguard certain species from over-exploitation. CITES was conceived in the spirit of such cooperation. Today, it affords varying degrees of protection to more than 35,000 species of animals and plants, whether they are traded as live specimens, fur coats or dried herbs. CITES is an international agreement to which countries adhere voluntarily. CITES does not take the place of national laws, but it provides a framework to be respected by each Party, which has to adopt its own domestic legislation to ensure that CITES is implemented at the national level (CITES undated, accessed May 19, 2022).

4.8.5 International Union for Conservation of Nature

The International Union for Conservation of Nature (IUCN) is a membership Union composed of both government and civil society organizations (IUCN undated a, accessed September 16, 2021). The IUCN lists Venus flytrap as Vulnerable since 2000 (Schnell et al, 2000; IUCN undated b, accessed May 19, 2022). This status provides no legal protection for the species.

4.8.6 Horticulture Trade and Commercial Availability

Venus flytrap plants are now common in cultivation and there are many commercial sources to supply hobby carnivorous plant enthusiasts. Venus flytrap plants have been cultivated using tissue culture techniques for many years. This process allows mass production of plants in a short period of time and at low price. The availability of a large quantity of affordable Venus flytrap plants in the horticulture trade reduces the need to obtain specimens from the wild. The International Carnivorous Plant Society web page lists 130 named cultivars of Venus flytrap (International Carnivorous Plant Society undated b, accessed May 19, 2022). According to Bailey and McPherson (2012, p. 146) many additional cultivars have not been formally

registered. Bailey and McPherson (2012, pp. 335-345) provide information about several plant nurseries that grow ethically sourced Venus flytrap and other carnivorous plants for the horticulture trade.

4.8.7 International Carnivorous Plant Society

According to their web page, The International Carnivorous Plant Society (ICPS, undated, accessed May 19, 2022) “is an organization of horticulturists, conservationists, scientists, and educators all interested in sharing knowledge and news of carnivorous plants.” The Society supports a variety of research projects on carnivorous plants and provides funds for management of natural areas that support carnivorous plant species (ICPS, undated, accessed May 19, 2022). According to their conservation policies online, they condemn collection of plants from the wild and introduction of plants into the wild outside of their natural range and not part of a valid restoration project as unethical (ICPS, undated, accessed May 19, 2022).

4.8.8 Venus Flytrap Champions

The Venus Flytrap Champions recognizes and assists landowners and land managers in the Carolinas who want to care for populations of this rare carnivorous species. The goal of this organization is to collaborate with a variety of state and federal agencies and nonprofit organizations to create a support network for landowners who want to manage Venus flytrap habitat on private property.

4.8.9 Venus Flytrap License Plate

A specialty Venus Flytrap license plate has been proposed in NC. Proceeds from plate purchases will support efforts of the North Carolina Botanical Garden Foundation, Inc. and Friends of Plant Conservation, Inc. to conserve native plants and promote the restoration of healthy landscapes across NC. The specialty plate has not yet been approved by the North Carolina State Legislature.

4.8.10 Recent and Ongoing Research

NCNHP biologists conducted a range-wide status survey of Venus flytrap (Hamon et al. 2021a, entire). In addition to the status survey for Venus flytrap, Hamon (2022, entire) also completed dissertation research on the pollination ecology of this species. Researchers at the University of North Carolina Chapel Hill Center for Genomic Sciences (Gregory Copenhaver, Corbin Jones, and Jamie Winshell) and the NC Botanical Garden (Johnny Randall) are currently working on a population genetics and phylogeography study. At Duke University, the William Morris lab is conducting experiments on the demography of Venus flytrap and looking at response to drought, nutrient input and low prey availability as well as local adaptation (Morris 2018, pers. comm.). At Coastal Carolina University, studies are underway in the Michelle Barthet lab to look at mycorrhizal associations with Venus flytrap (A. Carnaggio 2022, pers. comm.). The NCNHP also conducted a status survey on the Venus flytrap Cutworm moth, an insect species closely associated with Venus flytrap (Hamon et al. 2021b, entire).

CHAPTER 5: FUTURE CONDITIONS

5.1 Approach

To assess the future condition of Venus flytrap, we evaluated what this species may have in terms of resiliency, redundancy, and representation under six plausible future scenarios. As outlined in Chapter 4, the primary factors influencing the viability of Venus flytrap include habitat degradation and loss resulting from fire suppression; conversion of suitable forest or wetland habitats to other land uses, including development, pine plantations, and agriculture; and active land management (prescribed fire), which is beneficial to the species at the appropriate interval. We focused our future conditions analysis on how management of Venus flytrap habitats may be impacted by urbanization and climate change in the future.

We considered a future time frame of 50 years (2070), looking at changes at decadal intervals that were subsequently summarized to 30-year and 50-year time steps that ultimately account for normal variation in plant reproduction and responses to environmental conditions. We were reasonably certain we could forecast the response of Venus flytrap populations to varying levels of management efforts, as well as different urbanization projections, within this time period. Therefore, we summarized future population resiliency conditions for each management scenario at 2050 and 2070. The time steps began in 2020 (considered baseline), as this was the end of our current condition timeframe.

5.2 Data

5.2.1 Future Climate Conditions

In order to predict future changes in climate, scientists rely on climate model simulations that are driven by assumptions about future human population growth, changes in energy generation and land use, socio-economic development, and technology change. The Intergovernmental Panel on Climate Change (IPCC) was created to provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options (IPCC 2022, unpaginated). Groups such as the IPCC use multiple scenarios that depict trajectories of future greenhouse gas (GHG) emissions (also known as emission scenarios) because it is extremely difficult to accurately predict how human societies will change over multiple decades. These scenarios are based on assumptions about plausible future changes for four factors that are the dominant drivers of GHG emissions: population growth, economic growth or per capita gross domestic product (GDP), energy intensity of GDP, and the carbon intensity of energy production (Blanco et al. 2014, p. 357). Collectively, these four factors form the core of socioeconomic scenarios used in IPCC assessment reports (AR). A combination of scenarios can produce a reasonable range of plausible outcomes (Terando et al. 2020, p. 8). The use of different emission scenarios in climate models leads to different projections that reflect a range of possible climate futures.

While scenarios used by the IPCC in earlier assessments (the first through fourth assessments) assumed a particular combination of socioeconomic or emission trajectories, a prescribed set of radiative forcing scenarios (or pathways) known as Representative Concentration Pathways (RCPs) were used in the IPCC AR5. The RCPs are representative of several different scenarios that have similar GHG emissions characteristics on a time-dependent trajectory to reach a certain projected outcome (Wayne 2013, p.1). There are five RCPs, identified by the amount of radiative

forcing (i.e., the change in energy in the atmosphere due to GHG) reached by 2100: one high pathway (RCP 8.5); two intermediate stabilization pathways (RCP 6.0 and RCP 4.5); and one low trajectory pathway (RCP 2.6 and RCP 3PD) (Wayne 2013, p.11). RCP 8.5 assumes that emissions would be more or less unabated due to a lack of climate-change reversal policies (Wayne 2013, p.15). For RCP 4.5 and RCP 6.0, emissions are assumed to be relatively stable throughout the century, and RCP 4.5 incorporates a number of climate policies into forecasts (Wayne 2013, p.15). RCP 2.6 and RCP 3PD are not seen as plausible based on more recent climate information (IPCC 2021, entire).

The sixth Assessment Report (AR6), published in 2021, presents the most recent climate findings based on a set of scenarios that use Shared Socioeconomic Pathways (SSPs). The SSPs are scenarios of projected socioeconomic global changes out to the year 2100. The SSPs look at five different ways in which the world might evolve in the absence of climate policy and how different levels of climate change mitigation could be achieved when the mitigation targets of RCPs are combined with the SSPs. The SSP scenarios are (Hausfather 2018, p. 2):

- SSP1: Sustainability - Taking the Green Road (low challenges to mitigation and adaptation);
- SSP2: Middle of the Road (medium challenges to mitigation and adaptation);
- SSP3: Regional Rivalry - A Rocky Road (high challenges to mitigation and adaptation);
- SSP4: Inequality - A Road Divided (low challenges to mitigation, high challenges to adaptation);
- SSP5: Fossil-Fueled Development - Taking the Highway (high challenges to mitigation, low challenges to adaptation)

While there are new scenarios presented in the AR6 report, a graphical comparison shows that the SSP scenarios yield global CO₂ emissions, concentrations, and temperatures within similar ranges of previous scenario sets such as the RCPs (Figure 5-1):

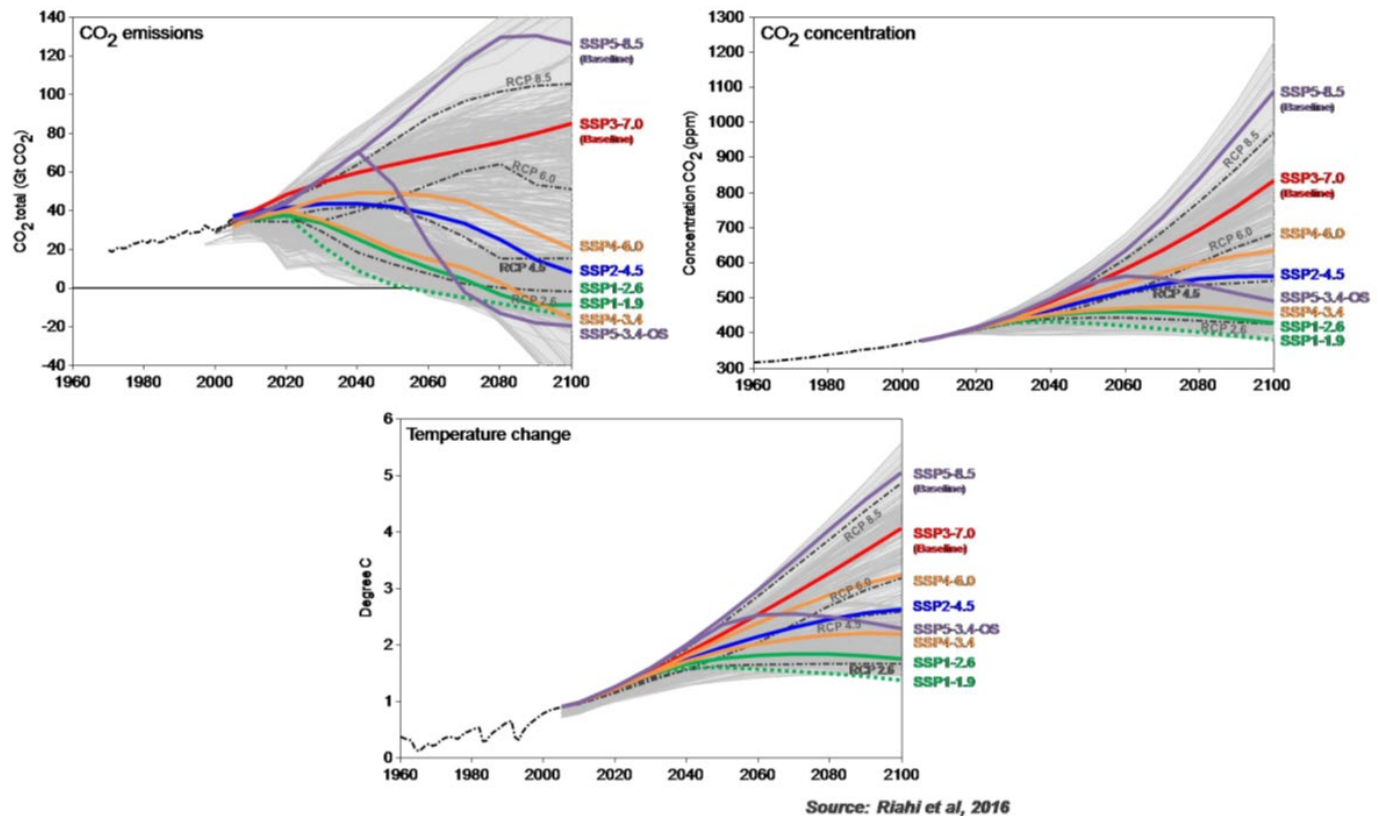


Figure 5-1. A comparison of carbon dioxide emissions (top left) and resulting atmospheric concentrations (top right), and temperature (bottom center) over the next century for both SSPs (colored lines) and RCPs (black dashed lines) (source: O'Neill et al. 2016, Figure 3). Note SSP2 relates to RCP 4.5 and SSP5 relates to RCP 8.5.

When taking into account future climate predictions, we considered the climate futures under SSP2 and SSP5 out to 2070, with SSP5 (“Higher Emissions”) projects a possible future in which global emissions of heat-trapping gases continue to increase through the 21st century, whereas SSP2 (“Lower Emissions”) projects a possible future in which the global emissions of heat-trapping gasses peak around 2040 and then decline (U.S. Climate Resilience Toolkit 2019, entire).

5.2.2 Future Land Use Change

Future land use and land cover change was measured using the U.S. EPA Integrated Climate and Land-Use Scenarios (ICLUS) dataset. This dataset provides spatially explicit projections of population and land use based on the IPCC scenarios and pathways approach, as described above (USEPA, undated). These projections are broadly consistent with peer-reviewed storylines of population growth and economic development that are widely used by the climate change impacts community. ICLUS explores future changes in land use and land cover, human population, housing density, and impervious surface for the United States (USEPA, undated). ICLUS uses population projections as inputs to a land use change model, which spatially allocates residential land uses based on projected population density, as well as commercial and industrial uses.

We assessed two future scenarios using the SSP 2 and SSP 5 storylines. The SSP storylines represent different trajectories of population and land use change that stem from global population and urbanization assumptions (explained above). SSP2 represents a 'business as usual' trajectory in which social, economic, and technological trends do not shift markedly from historical patterns, and is similar to the RCP 4.5 emissions scenario. SSP5 represents a trajectory with rapid population and economic growth, and is similar to the RCP 8.5 emissions scenario.

5.2.3 Future Suitable Prescribed Burning Windows

Prescribed fire management for the Venus flytrap aims to mimic the activity of natural wildfires, which are usually caused by lightning strikes during the summer months, or the growing season for Venus flytrap. Burn timing depends on meeting a range of suitable weather and fuel conditions, known as the prescription burn window, to allow safe and effective fire management outcomes (Kupfer et al. 2020, p. 764). Climate change is expected to impact factors such as temperature, relative humidity, and wind speed, which will affect the ability to engage in prescribed burning management in the future. To measure future changes in prescribed burning suitability, the USGS developed the Historical and Future Prescribed Burns Windows for the Southeast United States dataset (Kupfer et al. 2021, entire). This dataset assesses the impact of future climate change on burn window criteria (maximum daily temperature, daily average relative humidity, and daily average wind speed) that will affect suitable prescribed burn windows. Changes in the burn window criteria were assessed using projections from an ensemble of Global Climate Models (GCMs) under two greenhouse gas emissions, RCP 4.5 and RCP 8.5 (Kupfer et al. 2021, entire).

5.2.4 Protection Status

The permanent protection of Venus flytrap populations is important to the species' resiliency. Protected populations (that are also managed) provide the best refugia for this species. Sites currently in private conservation organization ownership (conservation organizations and land trusts), public ownership (national forests, state-owned parks, plant conservation preserves, game lands and forests, and local government) or private lands under permanent conservation easement will likely remain in protected status in the future. For the purposes of analyzing the future condition of Venus flytrap, we considered populations owned entirely by government agencies with a conservation focus (US Forest Service, NCDPR, NC Plant Conservation Program, NC Wildlife Resources Commission, NC Forest Service, NCNHP Dedicated Nature Preserves and New Hanover County Parks and Recreation) or private conservation organizations (The Nature Conservancy, Horry County Conservation Foundation and NC Coastal Land Trust) to have a high level of protection. Populations that occur on mixed ownership lands, meaning both conservation lands and private lands (non-conservation focused lands or NCNHP Registered Natural Areas) are considered to have a moderate level of protection. We also determined that populations occurring on military bases have a moderate protection level due to potential impacts from future training activities or land use changes. All other populations occurring on privately owned land with no conservation easement or other protection likely are considered to have a low level of protection.

5.3 Methodology

As detailed above, maintaining and managing Venus flytrap habitat with prescribed fire is essential to maintaining species viability over time. We performed spatial analyses to project changes in land cover under various levels of development over time to assess potential habitat loss due to urbanization and development. To characterize future prescribed fire management potential, we considered factors that affect fire management likelihood: (1) suitable prescribed burning windows during the growing season (June-Aug), (2) burn concern, which equates to proximity of developed areas to where prescribed burning takes place, and (3) burn feasibility, which is based on the combination of the area occupied by the Venus flytrap population, the protection status of the population, and management levels.

5.3.1 Habitat Loss

We used ICLUS land use change projections under two different development scenarios, SSP 2 and SSP 5 at decadal intervals from 2030-2070, and present results for two time periods, 2050 and 2070. The SSP 2 scenario projects a low development and urbanization scenario, whereas the SSP 5 scenario projects a high development and urbanization scenario. We analyzed natural and developed land cover within a 5.0 km (3.1 mi) buffer zone for each population. We calculated percent habitat loss using the following equation:

$$\text{Percent habitat loss} = 1 - (\text{Future habitat cover} / \text{Current habitat cover})$$

We considered populations projected to lose greater than 25% of natural cover within the 5.0 km (3.1 mi) buffer zone at 2050 and 2070 to have a high risk of development. We considered populations projected to lose less than 25% of their suitable habitat within the 5.0 km (3.1 mi) buffer at 2050 and 2070 have a low risk of development.

5.3.2 Burn Concern

We assessed the potential impacts of climate change on prescribed burning activity using the Historical and Future Prescribed Burns Windows for the Southeast United States dataset developed by the U.S. Geological Survey (Kupfer et al. 2021, entire). For each population, we assessed seasonal average estimates of percent suitable burn windows during the growing season (June-July-August) at decadal intervals from 2030 to 2070 for RCP 4.5 and RCP 8.5 greenhouse gas emission scenarios. Across all populations, the percent of suitable burn windows is predicted to decrease under each RCP scenario; however, at least 30% or more of each season (at least 27 days) is considered suitable for burning, even under the worst-case scenario (RCP 8.5 at 2070). After discussion with prescribed burning experts, this decrease in burn windows was not seen as an impediment to burning due to flexibility in burn timing, therefore we did not carry this metric forward.

The next metric we developed was burn concern, which is calculated as the percent of developed land cover within a 5.0 km (3.1 mi) buffer of each population. We assumed that areas with a higher percent of developed land cover will contain more smoke sensitive areas (e.g., schools, hospitals, homes, poultry houses, etc.) that will affect fire management and planning, due to the impacts of smoke dispersal. Areas with less developed cover will have fewer burning constraints than areas with high developed cover. We chose 5.0 km (3.1 mi) as a reasonable distance from a population based on management considerations for smoke distance guidelines (Campbell et al.

2020, entire) and to reduce spatial classification errors for ICLUS model predictions (Smith et al. 2002, p. 67). We assessed land cover within a 5.0 km (3.1 mi) buffer for each population using the ICLUS dataset, and reclassified land cover into developed and undeveloped classes. For the reclassified developed land cover class, we included ICLUS land cover classes with high population density and development cover. We categorized burn concern into three levels of concern, equating to percent of developed land cover within the 5.0 km (3.1 mi) buffer of each population, and assigned a score to each level (Table 5-1).

Table 5-1. Criteria to assign score to burn concern metric.

Level of Concern for Prescribed Burns	% Developed Land Cover within Population	Score
Low	<30%	3
Medium	30-50%	2
High	>50%	1

Thresholds for the level of concern cutoffs were made in consultation with prescribed fire practitioners (Starke 2022, pers. comm.). We examined the percent of developed land cover for each Venus flytrap population at decadal intervals from 2030 to 2070 under two climate scenarios – SSP2 (Scenario 1) and SSP5 (Scenario 2) (Appendix D).

5.3.3 Fire Management Potential

We assessed future fire management potential based on a combination of scores for the area occupied by the Venus flytrap population (size), the level of protection (as described in section 5.2.4 above (Protection Status), the burn concern metric (section 5.3.2), and management score under three different management scenarios (Table 5-3). We were unable to predict the number of plants and number of subpopulations used in the current condition analysis, so we did not carry those variables forward.

Table 5-2. Scores assigned to high, medium, and low categories of size (acreage), protection, burn concern, and management.

Score	Size (acres)	Protection Status	Burn Concern	Management
High = 3	>400	Public or Private Conservation Organization ownership	0-30% Developed	Managed with prescribed fire; majority of VFT habitat burned within a 1-4 year return interval
Medium = 2	200-400	Mixed ownership with various levels of conservation; military bases	30-50 % Developed	Managed with prescribed fire; majority of VFT habitat burned within a 5-8 year return interval
Low = 1	<200	Private ownership with no conservation easement	>50% Developed	Managed with prescribed fire or not; 9+ years return interval OR fire history unknown OR not managed at all

We assumed that populations that occupy a larger area were more likely to be managed with fire. We assumed that areas with higher levels of protected status would have higher potential for fire management due to conservation management objectives and increased motivation/resources to implement prescribed burns. We assumed that populations with higher burn concern would be less likely to be managed with fire due to higher proximity to developed areas that contain smoke sensitive areas, which may hinder fire management.

To assess different management regimes in the future, the management score from current condition was carried forward to calculate a management score for high, status quo, and low management scenarios (Table 5-3). To calculate a status quo management scenario, the management value for the current condition score remained unchanged. The low management scenario assumes that management levels will decrease in the future. To calculate low management scores, we reduced the current condition management score by 1, reducing it to a lower management class. The high management scenario assumes that management levels will increase in the future. To calculate high management scores, we increased the current condition management score by 1, increasing it to a higher management class.

Table 5-3. Changes to management score based on management level scenario.

Management Scenario	Calculation (Management Score)
Status Quo	Current Condition Management Score
High	Current Condition Management Score + 1
Low	Current Condition Management Score - 1

We calculated future fire management potential using a sum of weighted scores for size, protection status, burn concern, and management (Table 5-3). Protection status, burn concern, and management were assigned equal weights of 0.3, while size was weighted as 0.1. We assigned a fire management potential category of high, medium, and low based on the sum total score calculated for each population (Table 5-5). We assessed different approaches to weighting to determine the final weights in our calculation. Under an equal weighting approach with all variables weighed at 0.25, the number of low populations that received a high fire management potential score decreased due to the low size score; however, they scored high for protection, burn concern, and management. To minimize the impact of size on the potential improvement of these populations, we reduced the weight of the size metric to 0.1.

The sum total of the weighted metrics was then assigned a category of high, medium, and low based on its total (Table 5-5.) A total of >2.5 was assigned a score of high, 1.5-2.5 a score of medium, and <1.5 a score of low, with a maximum possible value of 3. Fire management

potential was calculated for the three management scenarios described above (Table 5-3) under the SSP 2 and SSP 5 development scenarios at decadal timesteps from 2030-2070.

Table 5-4. Summary of weights assigned to each fire management factor.

Size	Protection Status	Burn Concern	Management
0.1	0.3	0.3	0.3

Table 5-5. Categories for fire management potential scores.

Category	Fire Management Potential Total
High	>2.5
Medium	1.5-2.5
Low	<1.5

5.4 Future Resiliency

The potential influence of burn management on population resiliency was assessed by combining the risk of habitat loss and fire management potential scores for each population. To connect the fire management potential to future Venus flytrap population resiliency, we assessed what effect the risk of habitat loss and prescribed fire management potential value would have on the current condition resilience score for each population (Table 5-6). If the degree of habitat loss is low (<25% loss) and the fire management potential is high, the resilience score from current condition will increase by one. If habitat loss is low and the fire management potential is medium, the resilience score from current condition will remain the same. If the risk of habitat loss is low, and the fire management potential value is low, the resilience score will decrease by one. Under all management scenarios, if the risk of habitat loss is high (>25% loss), the resilience score from current condition will decrease by one.

Table 5-6. Interaction between habitat loss and fire management potential to determine future resiliency of Venus flytrap populations.

		Fire Management Potential		
		High	Medium	Low
Habitat Loss	<25% loss	Current Condition Resilience Score + 1	Current Condition Resilience Score	Current Condition Resilience Score - 1
	>25% loss	Current Condition Resilience Score - 1	Current Condition Resilience Score - 1	Current Condition Resilience Score - 1

Resilience scores were calculated for three different management scenarios and development scenarios (SSP 2 and SSP 5) at decadal intervals between 2030-2070 (Table 5-7). We predicted increases in future resiliency only for low populations because populations that are currently in high resiliency condition are in the highest possible condition, and those that are currently in

medium condition are not likely to move to a high resiliency condition based on the number of plants in those medium condition populations. As such, it will likely take many decades for those medium condition populations (currently with between 1,000-5,000 plants) to reach 10,000 or more plants, which is the threshold for the population size metric for high resiliency condition.

The results of our future conditions analysis indicate no change in the future resiliency of Venus flytrap populations that are currently in high resiliency condition, regardless of management scenario, climate scenario, and year (Table 5-7; Figure 5-2). Within management scenarios, the total resiliency conditions remained the same in 2050 and 2070 for SSP 2. SSP 5 showed greater variation within management scenarios and time steps. The eight populations currently in high resiliency condition are all predicted to remain in high resiliency condition 30 and 50 years into the future. This is primarily because these populations are currently protected and managed, and those conditions are not likely to change in the future. These highly resilient populations represent 92% of the area occupied by populations on the landscape (Figure 5-3).

Table 5-7. Summary of population resiliency across three management scenarios (high, status quo, low) and two development scenarios (SSP 2 and SSP 5) for 2050 and 2070.

Resiliency Class	Current Condition	Status Quo Management				Low Management				High Management			
		SSP 2		SSP 5		SSP 2		SSP 5		SSP 2		SSP 5	
		2050	2070	2050	2070	2050	2070	2050	2070	2050	2070	2050	2070
High	8	8	8	8	8	8	8	8	8	8	8	8	8
Medium	10	12	12	12	12	10	10	10	10	16	16	16	16
Low	56	46	46	41	37	27	27	25	23	47	47	44	40
Very Low	0	8	8	13	17	29	29	31	33	3	3	6	10

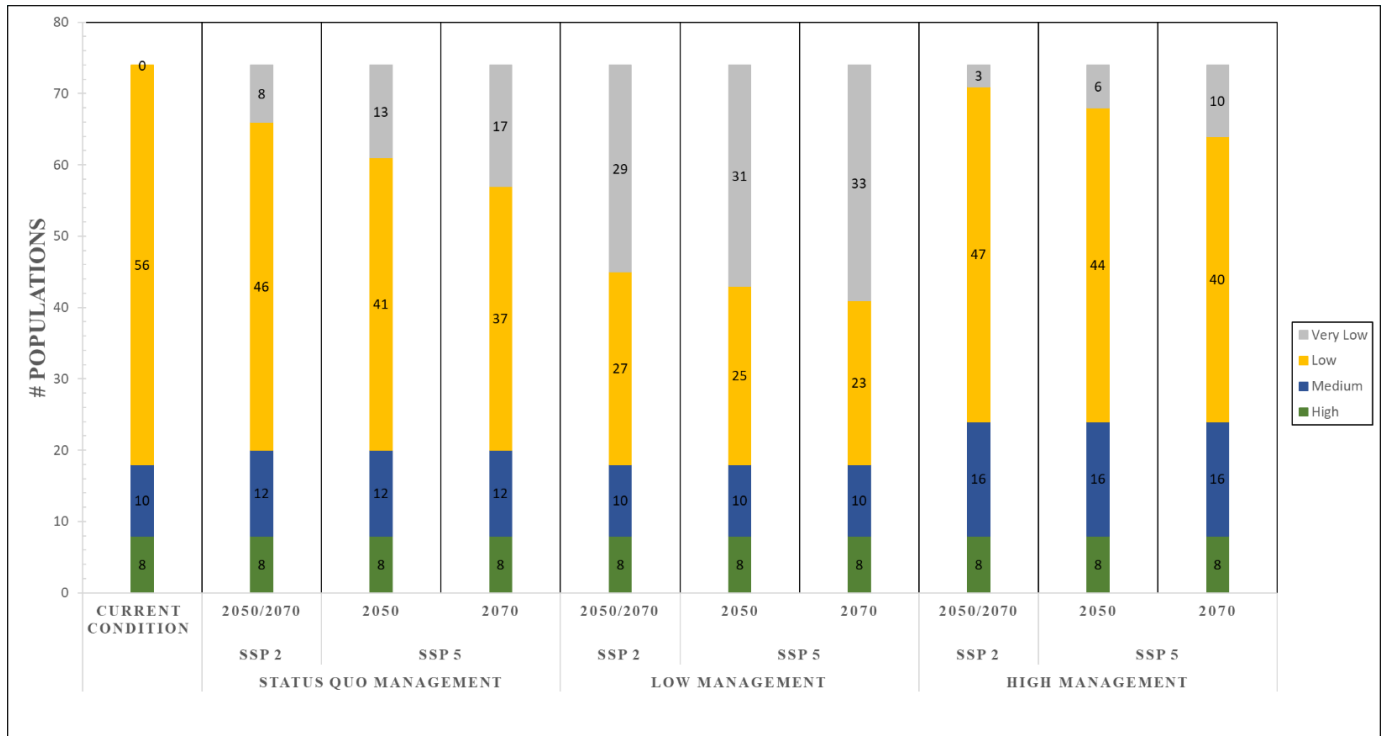


Figure 5-2. Overall resiliency of Venus flytrap populations under current condition and predicted future condition at 2050 and 2070, under three management scenarios and two climate scenarios.

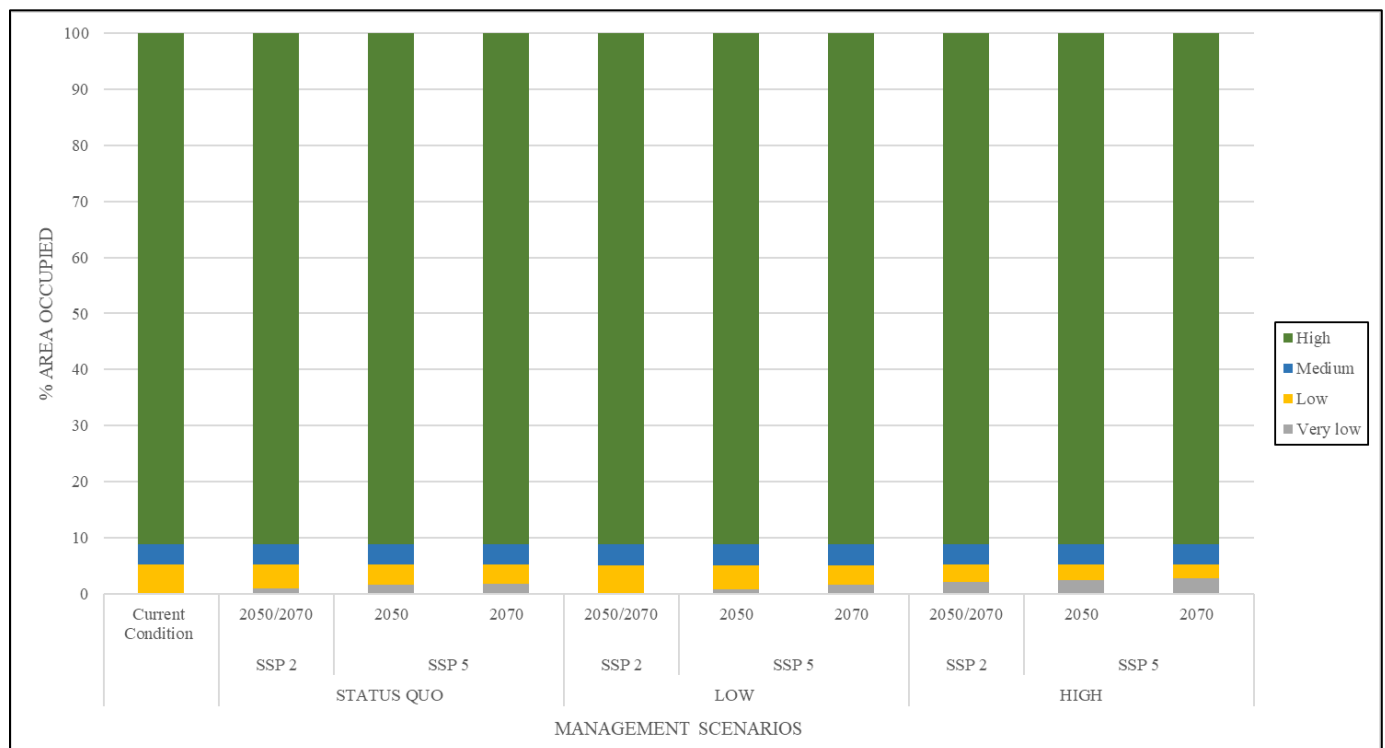


Figure 5-3. Percentage of area in different resiliency conditions for total area occupied under current condition, 2050, and 2070, for three management scenarios and two climate scenarios.

The populations that are currently in medium resiliency condition represent 3.6% of the area occupied by populations on the landscape (Figure 5-3). In the future, they either stay in medium resiliency condition under a low management scenario or show a slight increase under the status quo or high management scenarios (Table 5-7; Figure 5-2). These increases are primarily due to the potential for improvement of low resiliency populations with high management potential and low risk of habitat loss.

The populations currently in low resiliency condition represent 5% of the area occupied by populations on the landscape (Figure 5-3). In the future, these populations are predicted to remain in low resiliency condition, increase to medium resiliency, or drop to a very low resiliency condition. While there are many populations that are predicted to be in low condition (23 to 46 populations, representing approximately 3% of future populations by area on the landscape, depending on future management scenario; Figure 5-3) or very low condition (8 to 31 populations, representing 2% of the future populations by area on the landscape, depending on future management scenario; Figure 5-3), it is important to note that these populations are currently small (in terms of number of plants and area), isolated, not protected, and are not managed, and therefore not likely to be managed with fire in the future. It is uncertain whether these populations will remain on the landscape in the future.

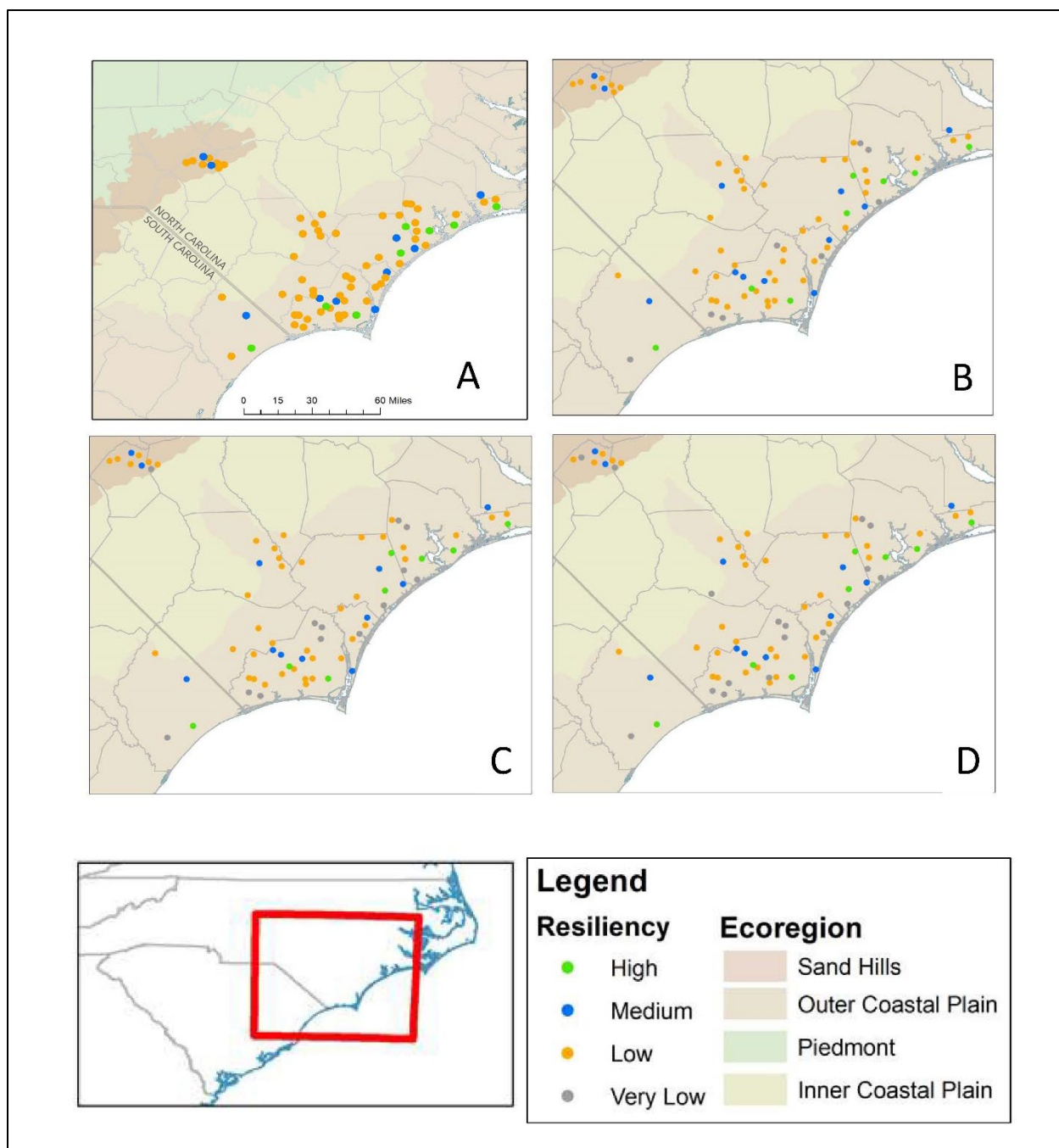


Figure 5-4. Map comparison of current condition (A) to status quo management scenario, SSP 2, 2050 and 2070 (B), status quo management scenario, SSP 5, 2050 (C), and status quo management scenario, SSP 5, 2070 (D).

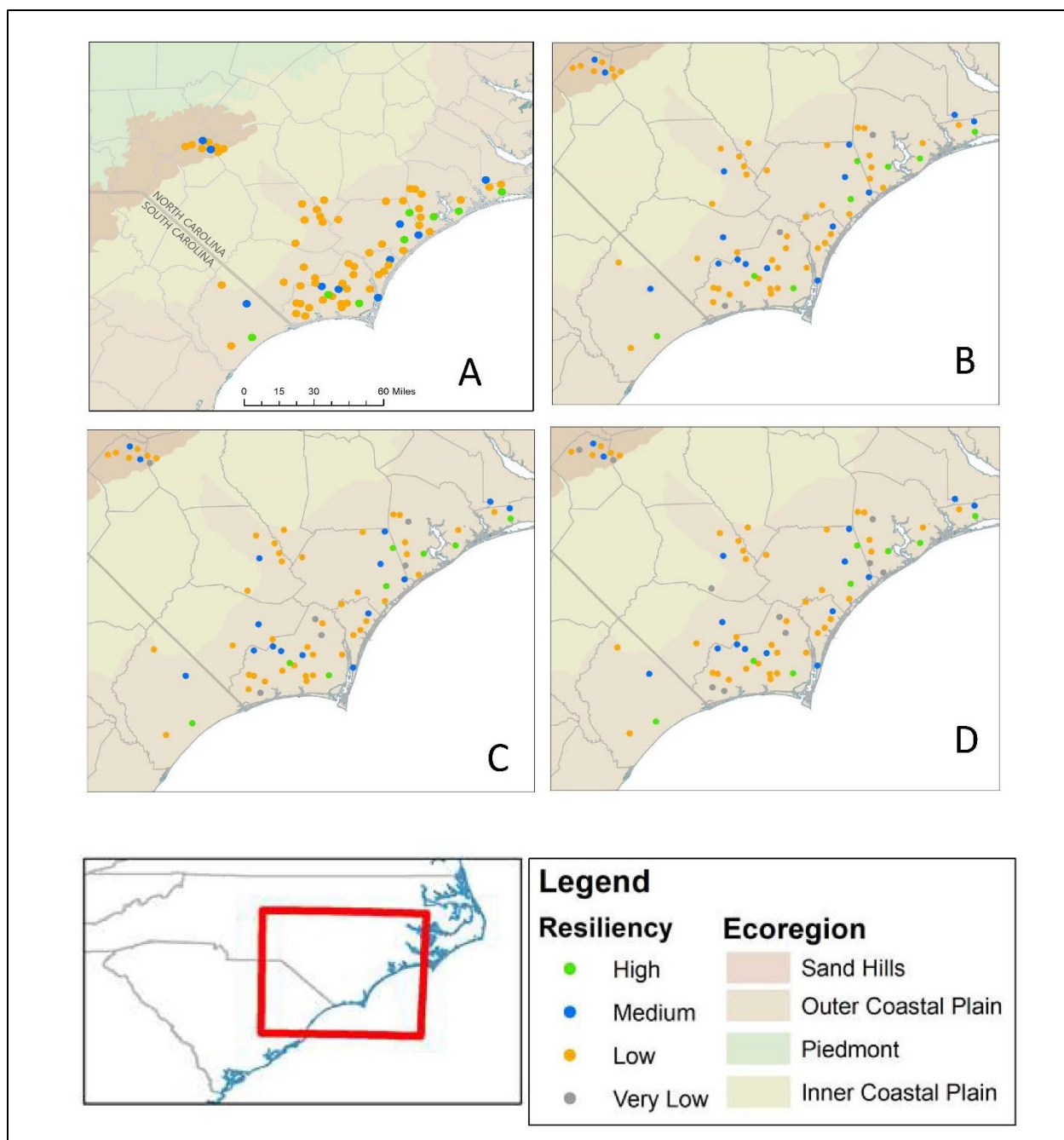


Figure 5-5. Map comparison of current condition (A) to high management scenario, SSP 2, 2050 and 2070 (B), high management scenario, SSP 5, 2050 (C), and high management scenario, SSP 5, 2070 (D).

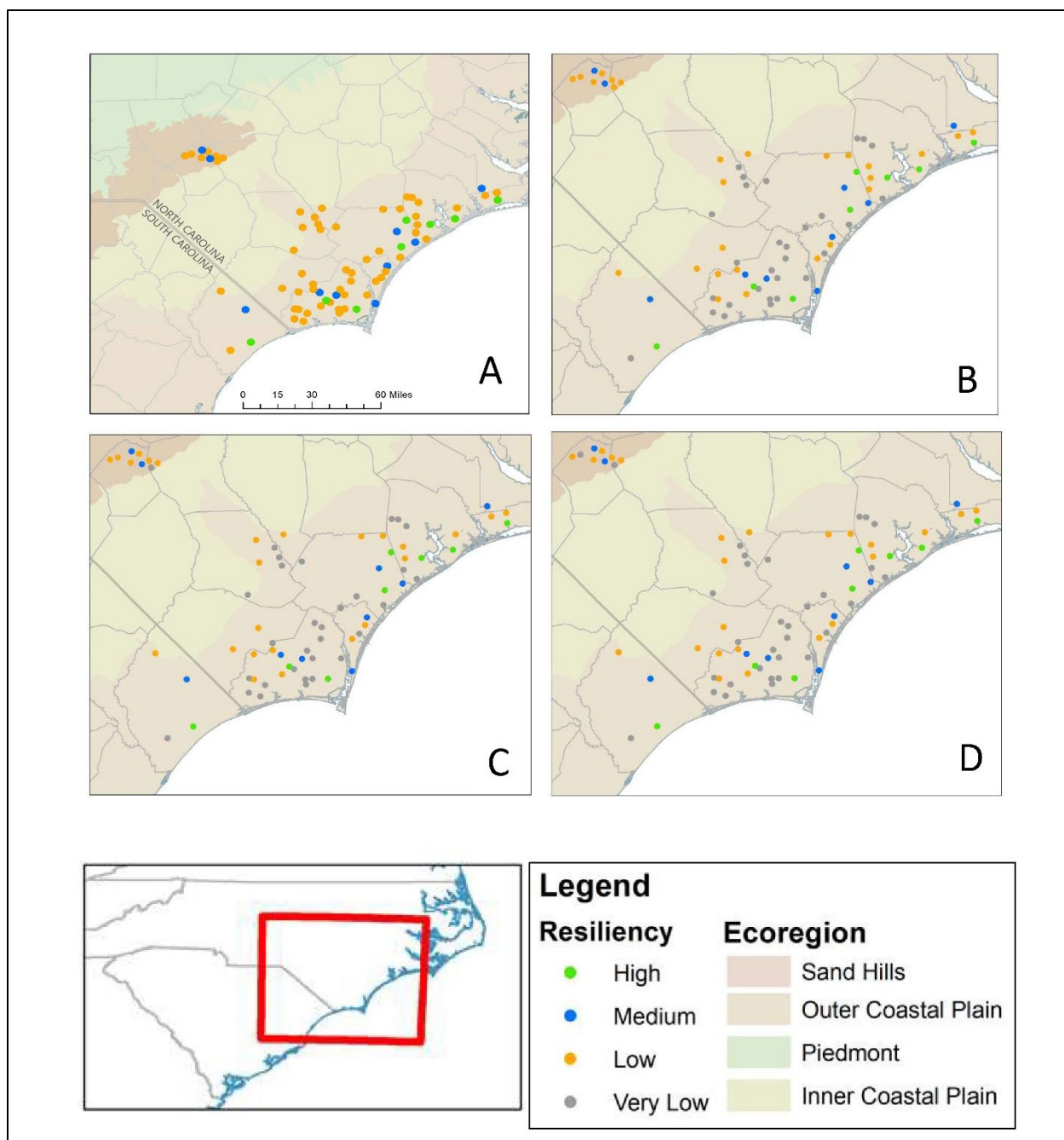


Figure 5-6. Map comparison of current condition (A) to low management scenario, SSP 2, 2050 and 2070 (B), low management scenario, SSP 5, 2050 (C), and low management scenario, SSP 5, 2070 (D).

5.5 Future Redundancy

The number and distribution of high resiliency populations of Venus flytrap are not predicted to change over the next 50 years (Figure 5-3). In 2070, regardless of climate future SSP2 or SSP5, there will likely be eight highly resilient Venus flytrap populations on the landscape, distributed throughout the known range in the Outer Coastal Plain of NC and SC.

Future medium resiliency Venus flytrap populations are predicted to remain well distributed across the Outer Coastal Plain. There is a predicted increase in both the number and distribution of these medium resiliency populations under high and status quo management (Figure 5-4, Figure 5-5).

Five percent of the area occupied by current Venus flytrap populations are in low condition; these low condition populations do not contribute to overall redundancy nor the ability to rescue the species from a catastrophic event. In the future, the low and very low resiliency populations are not expected to contribute to redundancy for the species. There will likely be small, isolated populations in low/very low condition throughout the range, comprising 72% of the populations under status quo management conditions and 75% of the populations under low management conditions in the future. Unless they are managed, there is a high probability of extirpation of these populations in the future.

5.6 Future Representation

Venus flytrap populations are known to occur in three ecoregions of NC and SC, but we do not know whether the species was historically distributed evenly throughout these ecoregions. We assume that the species was more widespread in the Outer Coastal Plain, as it is now, and it is predicted to remain so 50 years into the future (Figure 5-4).

The Venus flytrap's historical and current occupancy within a narrow range of the Coastal Plain ultimately limits aspects of its adaptive capacity, as it is unlikely to move across the landscape outside of its required habitat type to other suitable conditions, thus it is unable to "shift in space" (Thurman et al. 2020, p. 522). As described earlier in the document, Venus flytrap is subject to anthropogenic and climatic stressors that require a "persist in place" strategy, which it currently exhibits the ability to withstand, at least in some portions of its range. However, depending on future management, the species could lose representation in the Sandhills ecoregion.

Each ecoregion where Venus flytrap is found provides different geology, topography, climatic variability, soils, and other characteristics that drive biotic and abiotic environmental diversity and adaptive pressures. As long as management with fire enables species' persistence in these areas, the Venus flytrap's adaptive capacity will sustain the species into the future.

5.7 Summary of Future Condition

For our future conditions analysis, we measured how the threats of development, climate change, and management could affect the resiliency of Venus flytrap populations at decadal intervals up to 50 years into the future. We also examined how management with prescribed fire can affect overall species' viability in the future. We estimated resiliency condition across three different management scenarios; status quo, low management, and high management. Within each management scenario, we estimated resiliency condition for two climate scenarios (SSP 2 and SSP 5) at decadal intervals between 2030-2070. There were declines in the number of low resiliency populations across status quo and low management scenarios to a condition of very

low. In the status quo and high management scenarios, there was an increase in the number of medium resiliency populations. Within scenarios, we found a slight difference between climate scenarios (SSP 2 or SSP 5) and years (2050 or 2070). Management with prescribed fire is critical to species' viability. We assumed that if a population is protected and is surrounded by <25% of developed area then it will be managed with prescribed fire. Five out of eight highly resilient populations are located in protected areas and three are located on moderately protected military lands, containing 95% of the estimated known number of plants, and will likely be managed with prescribed fire and maintain resiliency into the future. Our analysis indicated slight changes to the number and distribution of medium resiliency populations when management with prescribed fire changes in the future, with opportunities for some of the small, low resiliency populations to increase due to high management potential and low risk of habitat loss. There are many populations that fall into the low or very low resiliency categories in the future, however these populations are small, isolated, and consist of only 5% of the area occupied by the species. We do not know the genetic contribution of these small, isolated populations.

Eight (11%) out of 74 extant Venus flytrap populations are predicted to remain highly resilient both 30 and 50 years into the future, and 10 to 16 (13%-21%) of the populations are predicted to remain in medium resiliency condition in the future, indicating that at least 24% of the populations are predicted to maintain resiliency into the future. These medium and highly resilient populations represent over 98% of the known plants and 95% of the total area currently occupied by the species. Species' redundancy may be reduced if the populations in the Sandhills are not managed adequately in the future, thus limiting the species range entirely to the Outer Coastal Plain. While the Venus flytrap occupies a narrow geographic range, species' representation, or adaptive capacity, is predicted to remain constant, provided that the protected populations remain managed with prescribed fire into the future. Management with prescribed fire is the key to maintaining Venus flytrap viability into the future.

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APPENDICES

APPENDIX A - Current Resiliency Summary for each Venus Flytrap Population

A-1. Metrics for each resiliency category and criteria for high, medium and low conditions.

Metrics	High = 3	Medium = 2	Low = 1
Number of individual plants	10,000+	1,000-10,000	<1,000
Number of Subpopulations	>5	2-5	1
Size (Acreage)	>400	200-400	<200
Management	Managed with prescribed fire; majority of VFT habitat burned within a 1-4 year return interval.	Managed with prescribed fire; majority of VFT habitat burned within a 5-8 year return interval.	Managed with prescribed fire or not; 9+ years return interval OR fire history unknown OR not managed at all.

A-2. Resiliency categories assigned by evenly divided summed scores.

Resiliency Category	Summed Scores
high	10-12
medium	7-9
low	4-6

A-3. Summary of resiliency scores for each extant Venus flytrap population sorted by sum of all scores and Heritage Program Population Number.

Heritage Program Population Number	# of Plants	# of Sub-populations	Management	Size (acres)	Sum	Resiliency Category
NC237	3	3	3	3	12	high
NC256	3	3	3	3	12	high
NC264	3	3	3	3	12	high
NC262	3	3	2	3	11	high
NC286	3	2	3	3	11	high
NC263	3	3	3	1	10	high
NC272	3	3	3	1	10	high
SC042	2	3	2	3	10	high
NC266	3	2	3	1	9	medium
NC287	2	3	2	1	8	medium
NC315	1	2	2	3	8	medium

NC027	2	1	3	1	7	medium
NC033	2	1	3	1	7	medium
NC167	2	1	3	1	7	medium
NC265	2	2	2	1	7	medium
NC275	1	2	3	1	7	medium
NC295	1	2	3	1	7	medium
SC029	1	2	1	3	7	medium
NC014	1	1	3	1	6	low
NC119	1	1	3	1	6	low
NC132	1	1	3	1	6	low
NC135	1	1	3	1	6	low
NC136	1	1	3	1	6	low
NC165	1	1	3	1	6	low
NC166	1	1	3	1	6	low
NC200	2	1	2	1	6	low
NC246	1	1	3	1	6	low
NC291	1	2	2	1	6	low
NC298	2	1	2	1	6	low
NC371	1	1	3	1	6	low
NC046	1	1	2	1	5	low
NC104	1	1	1	2	5	low
NC192	2	1	1	1	5	low
NC219	1	1	2	1	5	low
NC242	1	2	1	1	5	low
NC251	1	2	1	1	5	low
NC255	1	2	1	1	5	low
NC274	1	2	1	1	5	low
NC285	1	2	1	1	5	low
NC288	1	1	2	1	5	low
NC289	1	2	1	1	5	low
NC290	1	2	1	1	5	low
NC292	1	2	1	1	5	low
NC379	1	1	2	1	5	low
NC028	1	1	1	1	4	low
NC029	1	1	1	1	4	low
NC038	1	1	1	1	4	low
NC056	1	1	1	1	4	low
NC115	1	1	1	1	4	low
NC116	1	1	1	1	4	low
NC171	1	1	1	1	4	low
NC172	1	1	1	1	4	low
NC189	1	1	1	1	4	low
NC190	1	1	1	1	4	low

NC206	1	1	1	1	4	low
NC213	1	1	1	1	4	low
NC218	1	1	1	1	4	low
NC220	1	1	1	1	4	low
NC224	1	1	1	1	4	low
NC232	1	1	1	1	4	low
NC243	1	1	1	1	4	low
NC245	1	1	1	1	4	low
NC279	1	1	1	1	4	low
NC301	1	1	1	1	4	low
NC326	1	1	1	1	4	low
NC332	1	1	1	1	4	low
NC362	1	1	1	1	4	low
NC363	1	1	1	1	4	low
NC378	1	1	1	1	4	low
NC380	1	1	1	1	4	low
NC383	1	1	1	1	4	low
NC384	1	1	1	1	4	low
SC080	1	1	1	1	4	low
SC081	1	1	1	1	4	low

APPENDIX B - Adaptive capacity characterization

B-1. Based on seven themes and 12 core attributes from Thurman et al. (2020, entire).

Theme	Core Attribute	Adaptive Capacity Level	Evidence and Relevance
Distribution	Extent of Occurrence	Moderately High	Historical ~28,000km ² ; Current ~16,000km ² : Range-restricted species (only occurs in certain physiographic areas limited to Carolina Coastal Plain), most resilient in outer Coastal Plain.
	Habitat Specialization	Low	Habitat specificity: use of a restricted subset of wet pine savanna habitats; highly dependent on that particular habitat with well-defined physical and biotic characteristics.
	Commensalism with Humans	Moderately Low	Relatively low degree of tolerance; species is distributed across anthropogenically dominated landscape and can occur in backyards, but requires fire management that conflicts with human occupied landscape. Can occupy ROWs but best populations are in natural areas.
Evolutionary Potential	Genetic Diversity	Unknown	Genetics studies underway. Possibly neutral genetic diversity, meaning that there may be no direct effect on adaptive potential.
	Population Size	High	Multiple populations with >10,000 mature individuals
Movement	Dispersal Distance	Low	Species is characterized by severely restricted dispersal (<10m per dispersal event); gravity or rain disperses seeds
Abiotic Niche	Climatic Niche Breadth	Moderate	Narrow realized climate niche breadth because it is a restricted niche specialist that is not adapted to a wide range of abiotic conditions. However, survival of non-native populations in Florida and New Jersey (as well as introductions in western US) supports potential broader niche breadth.
	Physiological Tolerances	Moderate	Species physiological tolerances are mostly unknown but it is restricted to a narrow range of abiotic conditions, particularly with specific hydrology needs. Thermal tolerances are unknown, but it can withstand extreme events (pulse disturbances such as fire).
Ecological Role	Diet Breadth	High	Obtains energy through photosynthesis but can obtain nutrients from trapped arthropods.
Demography	Reproductive Phenology	Moderate	Self-compatible; flowers mid-May to mid-July; likely relies on environmental cues for timing and duration of reproductive events.
Life History	Life Span	Moderately Low	Long lived perennial; plants have grown in cultivation for ~25 years, but probably live ~10 years or less in the wild; generation time is high (~1 year); takes 4+ years to reach maturity
	Fecundity	Low	Produces ~ 200 seeds per plant per year, but low germination in the wild; germination requires light and moisture; number of successful propagules is low; young plants are killed by fire.

APPENDIX C - State Laws to Protect Venus Flytrap

C-1. Taking, etc., of certain wild plants from land of another

2005 North Carolina Code - General Statutes § 14-129. Taking, etc., of certain wild plants from land of another.

https://law.justia.com/codes/north-carolina/2005/chapter_14/gs_14-129.html

§ 14-129. Taking, etc., of certain wild plants from land of another.

No person, firm or corporation shall dig up, pull up or take from the land of another or from any public domain, the whole or any part of any Venus flytrap (*Dionaea muscipula*), trailing arbutus, Aaron's Rod (*Thermopsis caroliniana*), Bird-foot Violet (*Viola pedata*), Bloodroot (*Sanguinaria canadensis*), Blue Dogbane (*Amsonia tabernaemontana*), Cardinal-flower (*Lobelia cardinalis*), Columbine (*Aquilegia canadensis*), Dutchman's Breeches (*Dicentra cucullaria*), Maidenhair Fern (*Adiantum pedatum*), Walking Fern (*Camptosorus rhizophyllus*), Gentians (*Gentiana*), Ground Cedar, Running Cedar, Hepatica (*Hepatica americana* and *acutiloba*), Jack-in-the-Pulpit (*Arisaema triphyllum*), Lily (*Lilium*), Lupine (*Lupinus*), Monkshood (*Aconitum uncinatum* and *reclinatum*), May Apple (*Podophyllum peltatum*), Orchids (all species), Pitcher Plant (*Sarracenia*), Shooting Star (*Dodecatheon meadia*), Oconee Bells (*Shortia galacifolia*), Solomon's Seal (*Polygonatum*), Trailing Christmas (Greens-*Lycopodium*), Trillium (*Trillium*), Virginia Bluebells (*Mertensia virginica*), and Fringe Tree (*Chionanthus virginicus*), American holly, white pine, red cedar, hemlock or other coniferous trees, or any flowering dogwood, any mountain laurel, any rhododendron, or any ground pine, or any Christmas greens, or any Judas tree, or any leucothea, or any azalea, without having in his possession a permit to dig up, pull up or take such plants, signed by the owner of such land, or by his duly authorized agent. Any person convicted of violating the provisions of this section shall be guilty of a Class 3 misdemeanor only punished by a fine of not less than ten dollars (\$10.00) nor more than fifty dollars (\$50.00) for each offense. The provisions of this section shall not apply to the Counties of Cabarrus, Carteret, Catawba, Cherokee, Chowan, Cumberland, Currituck, Dare, Duplin, Edgecombe, Franklin, Gaston, Granville, Hertford, McDowell, Pamlico, Pender, Person, Richmond, Rockingham, Rowan and Swain. (1941, c. 253; 1951, c. 367, s. 1; 1955, cc. 251, 962; 1961, c. 1021; 1967, c. 355; 1971, c. 951; 1993, c. 539, s. 69; c. 553, s. 9; 1994, Ex. Sess., c. 24, s. 14(c); 2001-93, s. 1; 2001-487, s. 43(a).)

C-2. Plant Protection and Conservation Act

2015 North Carolina General Statutes

Chapter 106 - Agriculture.

Article 19B - Plant Protection and Conservation Act.

§ 106-202.19 - 19. Unlawful acts; penalties; enforcement.

Universal Citation: [NC Gen Stat § 106-202.19 \(2015\)](#)

Universal Citation: [NC Gen Stat § 106-202.19 \(2015\)](#)

<https://law.justia.com/codes/north-carolina/2015/chapter-106/article-19b/section-106-202.19>

Article 19B.

Plant Protection and Conservation Act.

§ 106-202.12. Definitions.

As used in this Article, unless the context requires otherwise:

- (1) "Board" means the North Carolina Plant Conservation Board as provided in this Article.
- (2) "Commissioner" means the Commissioner of Agriculture.
- (3) "Conserve" and "conservation" mean to use, and the use of, all methods and procedures for the purposes of increasing the number of individuals of resident species of plants up to adequate levels to assure their continuity in their ecosystems. These methods and procedures include all activities associated with scientific resource conservation such as research, census, law enforcement, habitat protection, acquisition and maintenance, propagation, and transplantation into unoccupied parts of historic range. With respect to endangered and threatened species, the terms mean to use, and the use of, methods and procedures to bring any endangered or threatened species to the point at which the measures provided for the species are no longer necessary.
- (4) "Endangered species" means any species or higher taxon of plant whose continued existence as a viable component of the State's flora is determined to be in jeopardy by the Board; also, any species of plant determined to be an "endangered species" pursuant to the Endangered Species Act.
- (5) "Endangered Species Act" means the Endangered Species Act of 1973, Public Law 93-205 (87 Stat. 884), as it may be subsequently amended.
- (6) "Exotic species" means a species or higher taxon of plant not native or naturalized in North Carolina but appearing in the Federal Endangered and Threatened Species List or in the appendices to the International Treaty on Endangered and Threatened Species.
- (7) "Plant" means any member of the plant kingdom, including seeds, roots and other parts or their propagules.

(8) "Protected plant" means a species or higher taxon of plant adopted by the Board to protect, conserve, and/or enhance the plant species and includes those the Board has designated as endangered, threatened, or of special concern.

(9) "Resident plant or resident species" means a native species or higher taxon of plant growing in North Carolina.

(10) "Scientific committee" means the North Carolina Plant Conservation Scientific Committee.

(11) "Special concern species" means any species of plant in North Carolina which requires monitoring but which may be collected and sold under regulations adopted under the provisions of this Article.

(12) "Threatened species" means any resident species of plant which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range, or one that is designated as threatened by the Federal Fish and Wildlife Service. (1979, c. 964, s. 1.)

§ 106-202.13. Declaration of policy.

The General Assembly finds that the recreational needs of the people, the interests of science, and the economy of the State require that threatened and endangered species of plants and species of plants of special concern be protected and conserved, that their numbers should be enhanced and that propagative techniques be developed for them; however, nothing in this Article shall be construed to limit the rights of a property owner, without his consent, in the management of his lands for agriculture, forestry, development or any other lawful purpose. (1979, c. 964, s. 1.)

§ 106-202.14. Creation of Board; membership; terms; chairman; quorum; board actions; compensation.

(a) The North Carolina Plant Conservation Board is created within the Department of Agriculture and Consumer Services.

(b) The Board shall consist of seven members who are residents of North Carolina, one of whom represents each of the following:

(1) The North Carolina Botanical Garden of The University of North Carolina at Chapel Hill;

(2) The botanical, scientific community in North Carolina;

(3) The North Carolina Forest Service of the Department of Agriculture and Consumer Services;

(4) A North Carolina citizens conservation organization;

- (5) The commercial plant production industry in North Carolina;
- (6) The Department of Agriculture and Consumer Services;
- (7) The North Carolina public at large.

The Governor shall appoint the first four members enumerated above; the Commissioner shall appoint the remaining three members.

(c) Initial appointments to the Board shall be made by October 1, 1979. Of the terms of initial appointees, the representatives of the North Carolina Botanical Garden of The University of North Carolina at Chapel Hill, the commercial plant production industry in North Carolina, and a North Carolina citizens conservation organization shall serve two-year terms; all other members shall serve four-year terms. All subsequent terms shall be for four-year terms.

(d) All members shall hold their offices until their successors are appointed and qualified. Any vacancy occurring in the membership of the Board prior to the expiration of the term shall be filled for the remainder of the unexpired term. The Commissioner may at any time remove any member from the Board for cause. Each appointment to fill a vacancy in the membership of the Board shall be of a person having the proper credentials for that vacancy and appointed by the proper appointing agency.

(e) The Board shall select its chairman from its own membership to serve for a term of two years. The chairman shall have a full vote. Any vacancy occurring in the chairmanship shall be filled by the Board for the remainder of the term. The Board may select other officers as it deems necessary.

(f) Any action of the Board shall require at least four concurring votes.

(g) Members of the Board who are not State employees shall receive per diem, subsistence and travel allowances authorized by G.S. 138-5; members who are State employees shall receive the subsistence and travel allowances authorized by G.S. 138-6; and members who are also members of the General Assembly shall receive subsistence and travel allowances authorized by G.S. 120-3.1. (1979, c. 964, s. 1; 1989, c. 727, s. 218(45); 1997-261, ss. 37, 38; 1997-443, s. 11A.119(a); 2011-145, s. 13.25(qq); 2013-155, s. 9.)

§ 106-202.15. Powers and duties of the Board.

The Board shall have all of the following powers and duties:

- (1) To adopt and maintain a list of protected plant species for North Carolina, identifying each entry by the common name and scientific name, along with its status as endangered, threatened, or of special concern, as provided under G.S. 106-202.16.
- (2) To reconsider and revise the lists from time to time in response to public proposals and as the Board deems necessary.

- (3) To conserve and to regulate the collection and shipment of those plant species or higher taxa that are of such similarity to endangered and threatened species that they cannot be easily or readily distinguished from an endangered or threatened species.
- (4) To regulate within the State any exotic species, in the same manner as a resident species if the exotic species is on the Federal Endangered and Threatened Species List or it is listed in the Appendices to the International Treaty to Conserve Endangered and Threatened Species.
- (5) To determine that certain plant species growing in North Carolina, whether or not they are on the endangered or threatened species list, are of special concern and to limit, regulate or forbid sale or collection of these plants.
- (6) To conduct investigations to determine whether a plant should be on the protected plant lists and the requirements for survival of resident species of plants.
- (7) To adopt regulations to protect, conserve and enhance resident and exotic species of plants on the lists, or to otherwise affect the intent of this Article.
- (8) To develop, establish and coordinate conservation programs for endangered species and threatened species of plants, consistent with the policies of the Endangered Species Act, including the acquisition of rights to land or aquatic habitats.
- (9) To enter into and administer cooperative agreements through the Commissioner of Agriculture, in concert with the North Carolina Botanical Garden and other agencies, with the U.S. Department of Interior or other federal, State or private organizations concerning endangered and threatened species of plants and their conservation and management.
- (10) To cooperate or enter into formal agreements with any agency of this State or of any other state or of the federal government for the purpose of enforcing any of the provisions of this Article.
- (11) Through the Commissioner, to receive funds, donations, grants or other moneys, issue grants, enter contracts, employ personnel and purchase supplies and materials necessary to fulfill its duties.
- (12) To adopt rules under which the Department of Agriculture and Consumer Services may issue permits to licensed nurserymen, commercial growers, scientific supply houses and botanical gardens for the sale or distribution of plants on the protected list provided that the plants are nursery propagated or grown horticulturally.
- (13) To stop the sale of or to seize any endangered, threatened, or special concern plant species, or part thereof possessed, transported, or moved within this State or brought into this State from any place outside the State if such is found by the Board or its duly authorized agent to be in violation of this Article or rules adopted pursuant to this Article. Such plants shall be moved or disposed of at the direction of the Board or its agent or by court order.

(14) To establish fees for permits authorized in this Article. (1979, c. 964, s. 1; 1989, c. 508, s. 1; 1997-261, s. 39; 2007-456, s. 1; 2019-204, s. 8(a).)

§ 106-202.16. Criteria and procedures for placing plants on protected plant lists.

(a) All native or resident plants which are on the current federal lists of endangered or threatened plants pursuant to the Endangered Species Act have the same status on the North Carolina Protected Plants lists.

(b) The Board, the Scientific Committee, or any resident of North Carolina may propose to the Department of Agriculture and Consumer Services that a plant be added to or removed from a protected plant list.

(c) If the Board, with the advice of the Scientific Committee, finds that there is any substance to the proposal, it shall publish notice of the proposal in a Department of Agriculture and Consumer Services news release.

(d) The Board shall collect relevant scientific and economic data, concerning any substantial proposal, necessary to determine:

(1) Whether or not any other State or federal agency or private entity is taking steps to protect the plant under consideration;

(2) The present or threatened destruction, modification or curtailment of its habitat;

(3) Over-utilization for commercial, scientific, educational or recreational purposes;

(4) Critical depletion from disease or predation;

(5) The inadequacy of existing regulatory mechanisms; or

(6) Other natural or man-made factors affecting its continued existence in North Carolina.

If the Board, with the advice of the Scientific Committee, finds that the plant should be added to or removed from a protected plant list the Board shall instigate rule-making procedures to add or remove the plant from the list.

(e), (f) Repealed by Session Laws 1987, c. 827, s. 31. (1979, c. 964, s. 1; 1987, c. 827, s. 31; 1997-261, s. 109.)

§ 106-202.17. Creation of committee; membership; terms; chairman; meetings; committee action; quorum; compensation.

(a) The North Carolina Plant Conservation Scientific Committee is created within the Department of Agriculture and Consumer Services.

- (b) The Scientific Committee shall consist of the Directors of The University of North Carolina at Chapel Hill Herbarium, the North Carolina State University Herbarium, the North Carolina Botanical Garden of The University of North Carolina at Chapel Hill, the North Carolina State Museum of Natural Sciences of the Department of Natural and Cultural Resources, and the North Carolina Natural Heritage Program of the Department of Natural and Cultural Resources or their designees, a representative of the North Carolina Association of Nurserymen, Inc., appointed by the Commissioner, and a representative of a conservation organization, appointed by the Commissioner. Members shall serve for three-year terms and may succeed themselves.
- (c) The Board shall select a chairman of the Scientific Committee from the Scientific Committee's membership to serve for three years.
- (d) The Scientific Committee may hold its meetings at the North Carolina Botanical Garden of The University of North Carolina at Chapel Hill.
- (e) Any action of the Scientific Committee shall require at least four concurring votes.
- (f) Members of the Scientific Committee who are not State employees may receive per diem, subsistence and travel allowances authorized by G.S. 138-5 if they so request; members who are State employees may receive the subsistence and travel allowances authorized by G.S. 138-6 if they so request; and members who are also members of the General Assembly may receive subsistence and travel allowances authorized by G.S. 120-3.1 if they so request. (1979, c. 964, s. 1; 1989, c. 727, s. 218(46); 1993, c. 561, s. 116(i); 1997-261, s. 109; 1997-443, s. 11A.119(a); 2007-456, s. 2; 2015-241, ss. 14.30(l), (w).)

§ 106-202.18. Powers and duties of the Scientific Committee.

The Scientific Committee shall have all of the following powers and duties:

- (1) To gather and provide information and data and advise the Board with respect to all aspects of the biology and ecology of endangered and threatened plant species.
- (2) To develop and present to the Board management and conservation practices for preserving endangered or threatened plant species.
- (3) To recommend habitat areas for acquisition to the extent that funds are available or expected.
- (4) To investigate and make recommendations to the Board as to the status of endangered, threatened plant species, or species of special concern.
- (5) To make recommendations to the Board concerning regulation of the collection and shipment of endangered or threatened plant species within North Carolina.

(6) To review and comment on environmental impact statements prepared by State agencies on projects that may affect protected plants; and

(7) To advise the Board on matters submitted to the Scientific Committee by the Board or the Commissioner which involve technical questions and the development of pertinent rules and regulations, and make any recommendations as deemed by the Scientific Committee to be worthy of the Board's consideration. (1979, c. 964, s. 1; 2007-456, s. 3.)

§ 106-202.19. Unlawful acts; penalties; enforcement.

(a) Unless the conduct is covered under some other provision of law providing greater punishment, it is unlawful to engage in any of the following conduct:

(1) To uproot, dig, take or otherwise disturb or remove for any purpose from the lands of another, any plant on a protected plant list without a written permit from the owner which is dated and valid for no more than 180 days and which indicates the species or higher taxon of plants for which permission is granted; except that the incidental disturbance of protected plants during agricultural, forestry or development operations is not illegal so long as the plants are not collected for sale or commercial use.

(2) To sell, barter, trade, exchange, export, offer for sale, barter, trade, exchange or export or give away for any purpose including advertising or other promotional purpose any plant on a protected plant list, except as authorized according to the rules and regulations of the Board.

(3) To violate any rule of the Board promulgated under this Article.

(4) Repealed by Session Laws 2012-200, s. 18, effective October 1, 2012.

(5) To buy ginseng outside of a buying season as provided by the Board without obtaining the required documents from the person selling the ginseng.

(6) To buy ginseng for the purpose of resale or trade without holding a currently valid permit as a ginseng dealer.

(6a) To uproot, dig, take, or otherwise disturb or remove for any purpose from another person's land ginseng, galax, or Venus flytrap without a written permit from the owner that is dated and valid for no more than 180 days. A person in lawful possession of the land who has a recorded lease which allows for the disturbance or removal of any vegetation on the land is not subject to this subdivision.

(6b) To buy galax outside of a buying season as provided by the Board without obtaining the required documents from the person selling the galax.

(6c) To buy Venus flytrap outside of a buying season as provided by the Board without obtaining the required documents from the person selling the Venus flytrap.

- (6d) To buy more than five pounds of galax for the purpose of resale or trade without a copy of the landowner's written permission and confirmation of the collection date.
- (6e) To buy more than 50 Venus flytrap plants for the purpose of resale or trade unless fully compliant with applicable regulations.
- (7) To fail to keep records as required under this Article, to refuse to make records available for inspection by the Board or its agent, or to use forms other than those provided for the current year or harvest season by the Department of Agriculture and Consumer Services.
- (8) To provide false information on any record or form required under this Article.
- (9) To make false statements or provide false information in connection with any investigation conducted under this Article.
- (10) To possess any protected plant, or part thereof, which was obtained in violation of this Article or any rule adopted under this Article.
- (11) To violate a stop sale order issued by the Board or its agent.
- (a1) Any person convicted of violating this Article, or any rule of the Board adopted pursuant to this Article shall be guilty of a Class 2 misdemeanor. Each illegal movement or distribution of a protected plant shall constitute a separate violation. In addition, if any person continues to violate or further violates any provision of this Article after written notice from the Board, the court may determine that each day during which the violation continued or is repeated constitutes a separate violation subject to the foregoing penalties.
- (a2) A civil penalty of not more than two thousand dollars (\$2,000) may be assessed by the Board against any person guilty of violating this Article a second or subsequent time. The clear proceeds of civil penalties assessed pursuant to this subsection shall be remitted to the Civil Penalty and Forfeiture Fund in accordance with G.S. 115C-457.2.
- (b) The Commissioner or any employee or agent of the Department of Agriculture and Consumer Services designated by the Commissioner to enforce the provisions of this Article, may enter any place within the State at all reasonable times where plant materials are being grown, transported, or offered for sale and require the presentation for inspection of all pertinent papers and records relative to the provisions of this Article, after giving notice in writing to the owner or custodian of the premises to be entered. If he refuses to consent to the entry, the Commissioner may apply to any district court judge and the judge may order, without notice, that the owner or custodian of the place permit the Commissioner to enter the place for the purposes herein stated and failure by any person to obey the order may be punished as for contempt.
- (c) The Commissioner of Agriculture is authorized to apply to the superior court for, and the court shall have jurisdiction upon hearing and, for cause shown, to grant a temporary or permanent injunction restraining any person from violating any provision of G.S. 106-202.19(a),

regardless of whether there exists an adequate remedy at law. (1979, c. 964, s. 1; 1989, c. 508, s. 2; 1993, c. 539, s. 749; 1994, Ex. Sess., c. 24, s. 14(c); 1997-261, ss. 40, 41; 1998-215, s. 9; 2001-487, s. 43(b); 2007-456, ss. 4, 5; 2012-200, s. 18.)

§ 106-202.20. Forfeiture of illegally possessed plants; disposition of plants.

Upon conviction of any defendant for a violation of G.S. 106-202.19, the court, in its discretion, may order the defendant to forfeit any plant or plant parts which he possesses in violation of G.S. 106-202.19. The court shall direct disposition of any forfeited plant or plant part by destruction or sale. The clear proceeds of forfeitures and sales pursuant to this section shall be remitted to the Civil Penalty and Forfeiture Fund in accordance with G.S. 115C-457.2. (1989, c. 508, s. 3; 1997-261, s. 109; 1998-215, s. 10.)

§ 106-202.21. Ginseng dealer permits.

- (a) No person shall act in the capacity of a ginseng dealer, or shall engage, or offer to engage in the business of, advertise as, or assume to act as a ginseng dealer unless that person holds a currently valid permit as provided in this Article.
- (b) Applications for a ginseng dealer permit shall be on a form and shall contain information as prescribed by the Board. All permits issued under this section shall expire on 30 June of the fiscal year for which they are issued.
- (c) A ginseng dealer permit may be renewed annually upon application to the Board.
- (d) A ginseng dealer shall notify the Board of any change of address or business location within 30 days of such change.
- (e) The Board shall issue to each applicant who satisfies the requirements of this Article a permit which entitles the applicant to conduct the business described in the application during the harvest season for which the permit is issued, unless the permit is suspended or revoked. (1989, c. 508, s. 3.)

§ 106-202.22. Denial, suspension, or revocation of permit.

- (a) The Board may deny, suspend, revoke, or modify any permit issued under this Article if it finds that the applicant or permit holder has violated this Article or rules adopted pursuant to this Article.
- (b) Suspension of any permit under this Article shall be for not less than one year. Any permit holder whose permit has been revoked shall not be eligible to reapply until two years after the final decision of the Board or two years after his permit is surrendered pursuant to such revocation, whichever is earlier. The expiration or voluntary surrender of a permit shall not deprive the Board of jurisdiction to suspend, revoke or modify such permit. A person whose permit has been suspended or revoked shall not engage in business as an employee, partner, or associate of another permit holder during the period of such revocation or suspension.

(c) If a permit is suspended or revoked, the permit holder shall, within five days of such suspension or revocation, surrender such permit to the Commissioner or his authorized representative. (1989, c. 508, s. 3.)

C-3. Felony law.

2014 North Carolina General Statutes

Chapter 14 - Criminal Law.

Article 22 - Damages and Other Offenses to Land and Fixtures.

§ 14-129.3 - 3. Felony taking of Venus flytrap. Universal Citation: NC Gen Stat § 14-129.3 (2014)

(House Bill 1059)

<https://law.justia.com/codes/north-carolina/2014/chapter-14/article-22/section-14-129.3/>

14-129.3. Felony taking of Venus flytrap.

(a) Any person, firm, or corporation who digs up, pulls up, takes, or carries away, or aids in taking or carrying away, any Venus flytrap (*Dionaea muscipula*) plant or the seed of any Venus flytrap plant growing upon the lands of another person, or from the public domain, with the intent to steal the Venus flytrap plant or seed is guilty of a Class H felony.

(b) This section shall not apply to any person, firm, or corporation that has a permit to dig up, pull up, take, or carry away the plant or seed, signed by the owner of the land, or the owner's duly authorized agent. At the time of the digging, pulling, taking, or carrying away, the permit shall be in the possession of the person, firm, or corporation on the land. (2014-120, s. 52(a).)

C-4. Destruction of sea oat or Venus's flytrap plants law.

2013 South Carolina Code of Laws

Title 16 - Crimes and Offenses

CHAPTER 11 - OFFENSES AGAINST PROPERTY

SECTION 16-11-590. Destruction of sea oat or Venus's flytrap plants.

<https://law.justia.com/codes/south-carolina/2013/title-16/chapter-11/section-16-11-590#:~:text=Destruction%20of%20sea%20oat%20or%20Venus's%20flytrap%20plants.,-Universal%20Citation%3A%20SC&text=It%20shall%20be%20unlawful%20for,property%20without%20the%20owner's%20consent.>

Universal Citation: [SC Code § 16-11-590 \(2013\)](#)

It shall be unlawful for any person to cut, collect, break or otherwise destroy sea oat plants, Venus's-flytrap plants or any part on public property or on private property without the owner's consent. Any person violating the provisions of this section shall be guilty of a misdemeanor and upon conviction shall be fined not more than two hundred dollars or imprisoned not more than thirty days nor less than five days. Each violation shall constitute a separate offense.

HISTORY: 1962 Code Section 16-385.2; 1961 (52) 427; 1980 Act No. 417.

APPENDIX D - Future Conditions Analysis

D-1. Table of future resiliency scores under status quo management scenario. Resiliency scores are presented for Integrated Climate and Land-Use Scenarios (ICLUS) development scenarios SSP2 and SSP5 between 2030-2070. H=High, M=Medium, L=Low, VL=Very low

Heritage Program Population Number	Status Quo Management									
	SSP 2					SSP 5				
	2030	2040	2050	2060	2070	2030	2040	2050	2060	2070
NC014	L	L	L	L	L	L	L	L	L	L
NC027	M	M	M	M	M	M	M	M	M	M
NC028	L	L	L	L	L	L	L	L	L	VL
NC029	L	L	L	L	L	L	L	L	L	L
NC033	M	M	M	M	M	M	M	M	M	M
NC038	M	M	M	M	M	M	M	M	M	M
NC046	M	M	M	M	M	M	M	M	M	M
NC056	M	M	M	M	M	M	M	M	M	M
NC104	L	L	L	L	L	L	L	L	L	L
NC115	L	L	L	L	L	L	L	L	L	L
NC116	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
NC119	L	L	L	L	L	L	L	L	L	L
NC132	L	L	L	L	L	L	L	L	L	L
NC135	L	L	L	L	L	L	L	L	L	L
NC136	L	L	L	L	L	L	L	L	L	L
NC165	L	L	L	L	L	L	L	L	L	L
NC166	L	L	L	L	L	L	L	L	L	L
NC167	M	M	M	M	M	M	M	M	M	M
NC171	L	L	L	L	L	L	L	L	L	L
NC172	L	L	L	L	L	L	L	L	L	L
NC189	L	L	L	L	L	L	L	L	L	L
NC190	L	L	L	L	L	L	L	L	L	L
NC192	L	L	L	L	L	L	L	L	L	L
NC200	L	L	L	L	L	L	L	L	L	L
NC206	L	L	L	L	L	L	L	VL	VL	VL
NC213	L	L	L	L	L	L	L	L	L	L
NC218	L	L	L	L	L	L	L	L	L	L
NC219	M	M	M	M	M	M	M	M	M	M
NC220	L	L	L	L	L	L	L	L	L	L
NC224	L	L	L	L	L	L	L	L	L	L

NC232	L	L	L	L	L	L	L	L	L	L
NC237	H	H	H	H	H	H	H	H	H	H
NC242	L	L	L	L	L	L	L	L	L	VL
NC243	L	L	L	L	L	L	L	L	L	L
NC245	L	L	L	L	L	L	L	L	L	L
NC246	L	L	L	L	L	L	L	L	L	L
NC251	L	L	L	L	L	L	L	L	L	L
NC255	L	L	L	L	L	L	L	L	L	L
NC256	H	H	H	H	H	H	H	H	H	H
NC262	H	H	H	H	H	H	H	H	H	H
NC263	H	H	H	H	H	H	H	H	H	H
NC264	H	H	H	H	H	H	H	H	H	H
NC265	M	M	M	M	M	M	M	M	M	M
NC266	M	M	M	M	M	M	M	M	M	M
NC272	H	H	H	H	H	H	H	H	H	H
NC274	L	L	L	L	L	L	L	L	L	L
NC275	M	M	M	M	M	M	M	M	M	M
NC279	L	L	L	L	L	L	L	L	L	L
NC285	L	L	L	L	L	L	L	L	L	L
NC286	H	H	H	H	H	H	H	H	H	H
NC287	M	M	M	M	M	M	M	M	M	M
NC288	L	L	L	L	L	L	L	L	L	L
NC289	L	L	L	L	L	L	L	L	L	VL
NC290	L	L	L	L	L	L	L	L	L	L
NC291	L	L	L	L	L	L	L	L	L	L
NC292	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
NC295	M	M	M	M	M	M	M	M	M	M
NC298	L	L	L	L	L	L	L	L	L	VL
NC301	L	L	L	L	L	L	L	L	L	L
NC315	M	M	M	M	M	M	M	M	M	M
NC326	L	L	L	L	L	L	L	L	L	L
NC332	L	L	L	L	L	L	L	L	L	L
NC362	L	L	L	L	L	L	L	L	L	L
NC363	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
NC371	L	L	L	L	L	L	L	L	L	L
NC378	L	L	L	L	L	L	L	L	VL	VL
NC379	M	M	M	M	M	M	M	M	M	M
NC380	L	L	L	L	L	L	L	VL	VL	VL
NC383	L	L	L	L	L	L	L	L	L	L
NC384	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
SC029	M	M	M	M	M	M	M	M	M	M

SC042	H	H	H	H	H	H	H	H	H	H
SC080	L	L	L	L	L	L	L	L	L	L
SC081	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL

D-2. Table of future resiliency scores under status low management scenario. Resiliency scores are presented for Integrated Climate and Land-Use Scenarios (ICLUS) development scenarios SSP2 and SSP5 between 2030-2070. H=High, M=Medium, L=Low, VL=Very low

Heritage Program Population Number	Low Management									
	SSP 2					SSP 5				
	2030	2040	2050	2060	2070	2030	2040	2050	2060	2070
NC014	L	L	L	L	L	L	L	L	L	L
NC027	M	M	M	M	M	M	M	M	M	M
NC028	L	L	L	L	L	L	L	L	L	VL
NC029	L	L	L	L	L	L	L	L	L	L
NC033	M	M	M	M	M	M	M	M	M	M
NC038	L	L	L	L	L	L	L	L	L	L
NC046	L	L	L	L	L	L	L	L	L	L
NC056	L	L	L	L	L	L	L	L	L	L
NC104	L	L	L	L	L	L	L	L	L	L
NC115	L	L	L	L	L	L	L	L	L	L
NC116	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
NC119	L	L	L	L	L	L	L	L	L	L
NC132	L	L	L	L	L	L	L	L	L	L
NC135	L	L	L	L	L	L	L	L	L	L
NC136	L	L	L	L	L	L	L	L	L	L
NC165	L	L	L	L	L	L	L	L	L	L
NC166	L	L	L	L	L	L	L	L	L	L
NC167	M	M	M	M	M	M	M	M	M	M
NC171	L	L	L	L	L	L	L	L	L	L
NC172	L	L	L	L	L	L	L	L	L	L
NC189	L	L	L	L	L	L	L	L	L	L
NC190	L	L	L	L	L	L	L	L	L	L
NC192	L	L	L	L	L	L	L	L	L	L
NC200	L	L	L	L	L	L	L	L	L	L
NC206	L	L	L	L	L	L	L	VL	VL	VL
NC213	L	L	L	L	L	L	L	L	L	L
NC218	L	L	L	L	L	L	L	L	L	L
NC219	L	L	L	L	L	L	L	L	L	L
NC220	L	L	L	L	L	L	L	L	L	L

NC224	L	L	L	L	L	L	L	L	L	L
NC232	L	L	L	L	L	L	L	L	L	L
NC237	H	H	H	H	H	H	H	H	H	H
NC242	L	L	L	L	L	L	L	L	L	VL
NC243	L	L	L	L	L	L	L	L	L	L
NC245	L	L	L	L	L	L	L	L	L	L
NC246	L	L	L	L	L	L	L	L	L	L
NC251	L	L	L	L	L	L	L	L	L	L
NC255	L	L	L	L	L	L	L	L	L	L
NC256	H	H	H	H	H	H	H	H	H	H
NC262	H	H	H	H	H	H	H	H	H	H
NC263	H	H	H	H	H	H	H	H	H	H
NC264	H	H	H	H	H	H	H	H	H	H
NC265	M	M	M	M	M	M	M	M	M	M
NC266	M	M	M	M	M	M	M	M	M	M
NC272	H	H	H	H	H	H	H	H	H	H
NC274	L	L	L	L	L	L	L	L	L	L
NC275	M	M	M	M	M	M	M	M	M	M
NC279	L	L	L	L	L	L	L	L	L	L
NC285	L	L	L	L	L	L	L	L	L	L
NC286	H	H	H	H	H	H	H	H	H	H
NC287	M	M	M	M	M	M	M	M	M	M
NC288	L	L	L	L	L	L	L	L	L	L
NC289	L	L	L	L	L	L	L	L	L	VL
NC290	L	L	L	L	L	L	L	L	L	L
NC291	L	L	L	L	L	L	L	L	L	L
NC292	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
NC295	M	M	M	M	M	M	M	M	M	M
NC298	L	L	L	L	L	L	L	L	L	VL
NC301	L	L	L	L	L	L	L	L	VL	VL
NC315	M	M	M	M	M	M	M	M	M	M
NC326	L	L	L	L	L	L	L	L	L	L
NC332	L	L	L	L	L	L	L	L	L	L
NC362	L	L	L	L	L	L	L	L	L	L
NC363	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
NC371	L	L	L	L	L	L	L	L	L	L
NC378	L	L	L	L	L	L	L	L	VL	VL
NC379	L	L	L	L	L	L	L	L	L	L
NC380	L	L	L	L	L	L	L	VL	VL	VL
NC383	L	L	L	L	L	L	L	L	L	L
NC384	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL

SC029	M	M	M	M	M	M	M	M	M	M
SC042	H	H	H	H	H	H	H	H	H	H
SC080	L	L	L	L	L	L	L	L	L	L
SC081	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL

D-3. Table of future resiliency scores under status high management scenario. Resiliency scores are presented for Integrated Climate and Land-Use Scenarios (ICLUS) development scenarios SSP2 and SSP5 between 2030-2070. H=High, M=Medium, L=Low, VL=Very low

Heritage Program Population Number	High Management									
	SSP 2					SSP 5				
	2030	2040	2050	2060	2070	2030	2040	2050	2060	2070
NC014	M	M	M	M	M	M	M	M	M	M
NC027	M	M	M	M	M	M	M	M	M	M
NC028	L	L	L	L	L	L	L	L	L	L
NC029	L	L	L	L	L	L	L	L	L	L
NC033	M	M	M	M	M	M	M	M	M	M
NC038	M	M	M	M	M	M	M	M	M	M
NC046	M	M	M	M	M	M	M	M	M	M
NC056	M	M	M	M	M	M	M	M	M	M
NC104	L	L	L	L	L	L	L	L	L	L
NC115	L	L	L	L	L	L	L	L	L	L
NC116	L	L	L	L	L	L	L	L	L	L
NC119	L	L	L	L	L	L	L	L	L	L
NC132	L	L	L	L	L	L	L	L	L	L
NC135	L	L	L	L	L	L	L	L	L	L
NC136	L	L	L	L	L	L	L	L	L	L
NC165	L	L	L	L	L	L	L	L	L	L
NC166	L	L	L	L	L	L	L	L	L	L
NC167	M	M	M	M	M	M	M	M	M	M
NC171	L	L	L	L	L	L	L	L	L	L
NC172	L	L	L	L	L	L	L	L	L	L
NC189	L	L	L	L	L	L	L	L	L	L
NC190	L	L	L	L	L	L	L	L	L	L
NC192	L	L	L	L	L	L	L	L	L	L
NC200	L	L	L	L	L	L	L	L	L	L
NC206	L	L	L	L	L	L	L	L	L	L
NC213	L	L	L	L	L	L	L	L	L	L
NC218	L	L	L	L	L	L	L	L	L	L
NC219	M	M	M	M	M	M	M	M	M	M

NC220	L	L	L	L	L	L	L	L	L	L
NC224	L	L	L	L	L	L	L	L	L	L
NC232	L	L	L	L	L	L	L	L	L	L
NC237	H	H	H	H	H	H	H	H	H	H
NC242	L	L	L	L	L	L	L	L	L	L
NC243	L	L	L	L	L	L	L	L	L	L
NC245	L	L	L	L	L	L	L	L	L	L
NC246	L	L	L	L	L	L	L	L	L	L
NC251	L	L	L	L	L	L	L	L	L	L
NC255	L	L	L	L	L	L	L	L	L	L
NC256	H	H	H	H	H	H	H	H	H	H
NC262	H	H	H	H	H	H	H	H	H	H
NC263	H	H	H	H	H	H	H	H	H	H
NC264	H	H	H	H	H	H	H	H	H	H
NC265	M	M	M	M	M	M	M	M	M	M
NC266	M	M	M	M	M	M	M	M	M	M
NC272	H	H	H	H	H	H	H	H	H	H
NC274	L	L	L	L	L	L	L	L	L	L
NC275	M	M	M	M	M	M	M	M	M	M
NC279	L	L	L	L	L	L	L	L	L	L
NC285	L	L	L	L	L	L	L	L	L	L
NC286	H	H	H	H	H	H	H	H	H	H
NC287	M	M	M	M	M	M	M	M	M	M
NC288	L	L	L	L	L	L	L	L	L	L
NC289	L	L	L	L	L	L	L	L	L	L
NC290	L	L	L	L	L	L	L	L	L	L
NC291	L	L	L	L	L	L	L	L	L	L
NC292	L	L	L	L	L	L	L	L	L	VL
NC295	M	M	M	M	M	M	M	M	M	M
NC298	L	L	L	L	L	L	L	L	L	L
NC301	L	L	L	L	L	L	L	L	L	L
NC315	M	M	M	M	M	M	M	M	M	M
NC326	L	L	L	L	L	L	L	L	L	L
NC332	L	L	L	L	L	L	L	L	L	L
NC362	L	L	L	L	L	L	L	L	L	L
NC363	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
NC371	L	L	L	L	L	L	L	L	L	L
NC378	L	L	L	L	L	L	L	L	L	L
NC379	M	M	M	M	M	M	M	M	M	M
NC380	L	L	L	L	L	L	L	L	L	L
NC383	L	L	L	L	L	L	L	L	L	L

NC384	L	L	L	L	L	L	L	L	L	L
SC029	M	M	M	M	M	M	M	M	M	M
SC042	H	H	H	H	H	H	H	H	H	H
SC080	L	L	L	L	L	L	L	L	L	L
SC081	L	L	L	L	L	L	L	L	L	L

APPENDIX E – Edits To Updated Versions

Version 1.1 Edits

Page 4, Executive Summary, Paragraph 9, Changed “almost 99%” to “over 98%” due to a calculation error.

Page 16, Section 2.4, Paragraph 2, Corrected “Figure 4-4” to “Figure 2-4.”

Page 18, Section 2.4, Paragraph 1, Changed the word “Arch” to “River.”

Page 19, Section 2.7, Figure 2-5, Revised the title of the range map to be more accurate.

Page 28, Section 3.4, Figure 3-2, Moved comma inside quote.

Page 33, Section 3.5, Paragraph 2, Added the word “at” before “Sunny Point.”

Page 36, Section 4.2.1, Paragraph 1, Added the word “with” before “killing frosts.”

Page 37, Section 4.2.1, Paragraph 4, Removed an extra closed parentheses.

Page 40, Section 4.3, Paragraph 3, Corrected section 4.8.2 to 4.8.3.

Page 44, Section 4.7, Paragraph 1, Moved comma inside quote.

Pages 47-50, Section 4.8, Corrected section numbers for 4.8.3 - 4.8.10.

Page 66, Section 5.7, Paragraph 1, Changed “We saw” to “Our analysis indicated.”

Page 63, Section 5.7, Paragraph 2, Changed “almost 99%” to “over 98%” due to a calculation error.