

From: [Reid, Rebekah N](#)
To: [Marshall, Michael E](#)
Subject: SSA Comments from Janet
Date: Wednesday, May 16, 2018 10:51:56 AM
Attachments: [HENA SSA J Mizzi comments 1.pdf](#)
Importance: High

Hi Mike,

Janet asked to read the SSA and provide comments. Her comments are handwritten on the document so I scanned it (see attached). After trying to scan multiple times to get a complete document, it just wasn't cooperating so I gave up. The scanner made some of the pages black and skipped some pages but every page with a comment is there. Sorry that the scan is such a mess!

Overall, she said the first part was good but the second part with the stats was confusing. A lot of her comments have to do with clarification.

I'll be at NCTC next week (coincidentally for SSA training!) but will have access to email in the evening.

Thanks!

Rebekah Reid

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Chapter 1: INTRODUCTION

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The dwarf-flowered heartleaf (*Hexastylis naniflora*) is a species of plant endemic to the upper Piedmont region of western North Carolina and upstate South Carolina. The dwarf-flowered heartleaf has been listed as threatened under the Endangered Species Act of 1973, as amended (Act), since 1989 (FR 54 14964-14967). The Species Status Assessment (SSA) framework (USFWS 2016, entire) summarizes the information compiled and reviewed by the US Fish and Wildlife Service (Service), incorporating the best available scientific and commercial data, to conduct an in-depth review of the species' biology and threats, evaluate its biological status, and assess the resources and conditions needed to maintain long-term viability. The intent is for the SSA to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from listing to consultations to recovery.

A Recovery Plan for the species was never completed. However, over the last 29 years, the Service has worked closely with partners to make significant progress toward recovery of the species. The Service is initiating this SSA to aid in determining the appropriateness of reclassifying the species. In the event that the SSA does not support reclassification, the SSA will be used to inform the development of a Recovery Plan. Importantly, the SSA does not result in a decision by the Service on whether this species should be proposed for reclassification under the Act. Instead, this SSA provides a review of the available information strictly related to the biological status of the dwarf-flowered heartleaf. The reclassification decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies. The results of a proposed decision will be announced in the *Federal Register*, with appropriate opportunities for public input.

For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in its natural systems over time. Using the SSA framework (Figure 1.1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (Wolf *et al.* 2015, entire).

- **Resiliency** describes the ability of populations to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health;



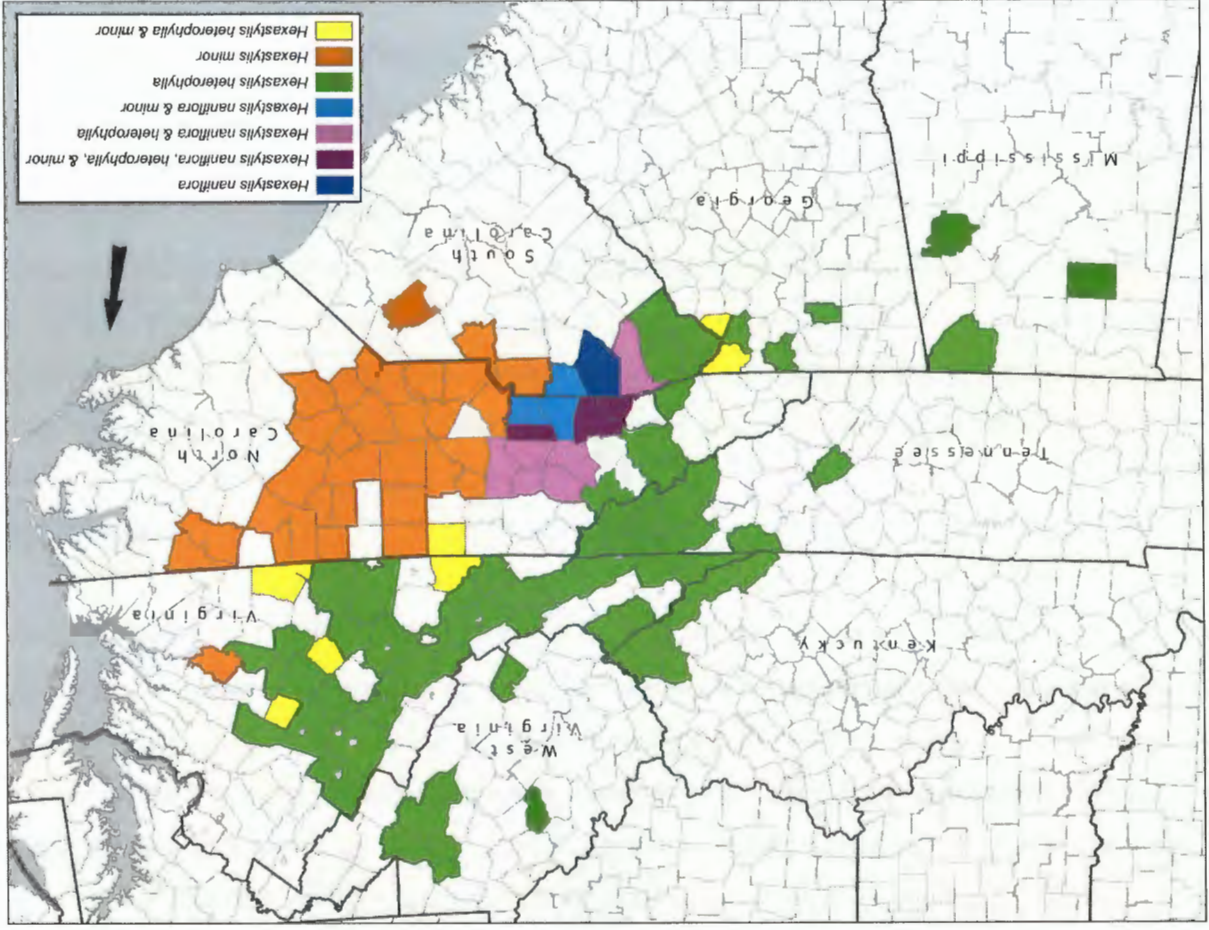
Figure 1.1. Species Status Assessment Framework

To evaluate the biological status of the dwarf-flowered heartleaf, both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation (together, the 3Rs). This SSA provides a thorough assessment of biology and natural history, and assesses demographic risks, stressors, and limiting factors in the context of determining the viability and risks of extinction for the species.

The format for this SSA includes: (1) Biology and Species Needs, (2) Current Conditions, (3) Influences on Viability, and (4) Future Conditions. This document is a compilation of the best available scientific and commercial information, and a description of past, present, and likely future risk factors to the dwarf-flowered heartleaf.

95 recognized as a genus (Niedenberger 2010). Additionally, most North American publications
 96 recognize *Hexastylis* at the generic level (Flora of North America 1997, Weakley 2015).

97
 98 The Service is not aware of any proposed changes in taxonomy that would affect the continued
 99 legal status of *H. naniflora* under the Act. However, within the range of *H. naniflora* there are
 100 populations which fall outside of the range of published values for key floral characteristics,
 101 overlapping with values described for *H. heterophylla* or *H. minor* (Figure 2.1; Weakley, 2010;
 102 Murrell et al. 2007; Gaddy 1987). These geographic areas of overlap in key characters have been
 103 the focus of recent genetic analyses (Murrell et al. 2007; Renninger, 2010; Murrell, 2015).



105 **Figure 2.1.** Distribution map showing county records for the three species in the *H. heterophylla*
 106 complex. Data was gathered from herbarium specimens, Element Occurrence Records (EORs)
 107 sheets and field studies. Based on Murrell et al. 2007.

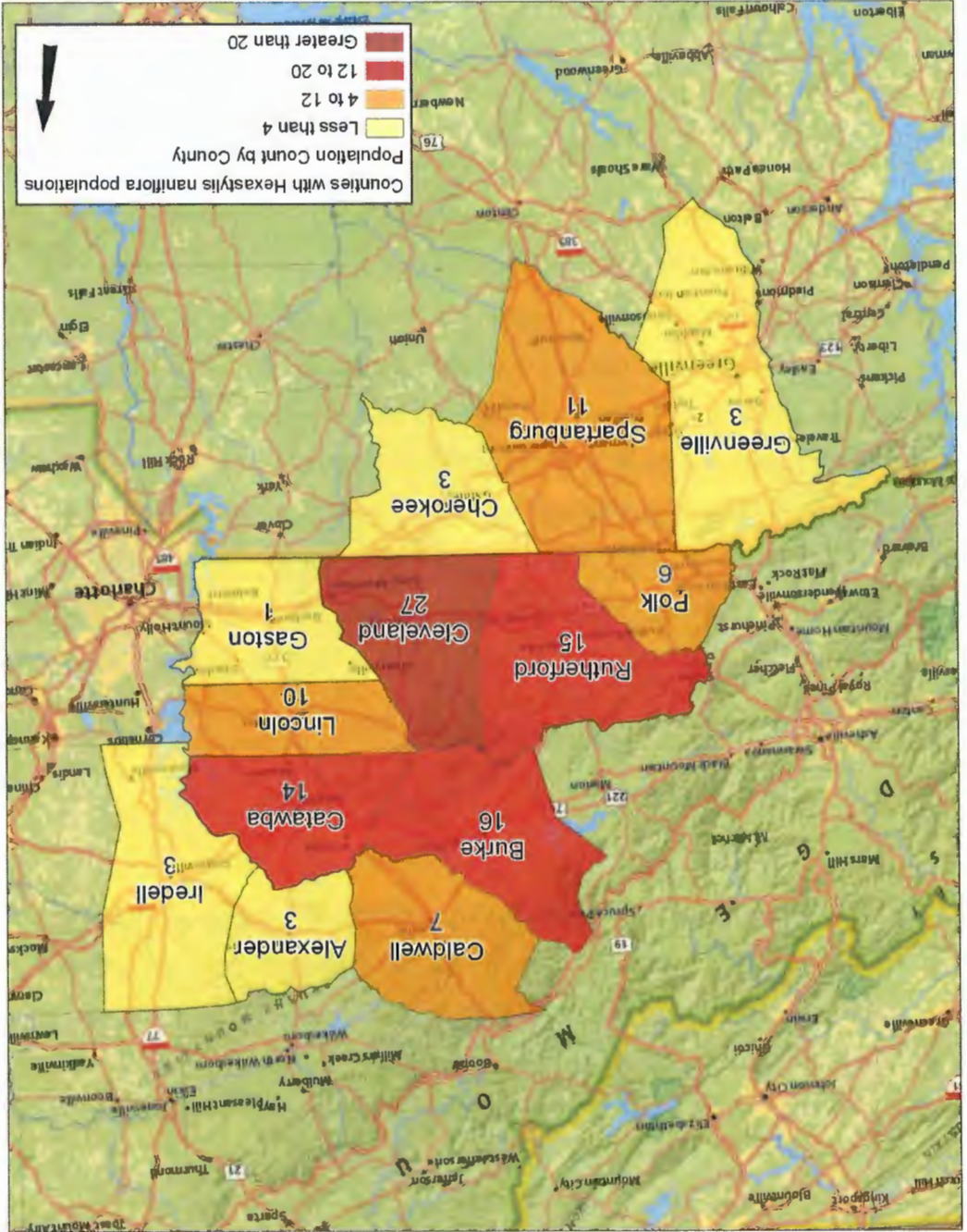


Figure 2.2. Current county distribution for dwarf-flowered heartleaf, with associated number of known populations within each county.

Many of those working with *Hexastylis naniflora* have used the terms “sub site”, “site”, “location”, “occurrence” (often, but not always, in reference to Natural Heritage Program Element Occurrence (EO) Records), “subpopulation” and “population” interchangeably. Others

176 three species within the Hexastylis Heterophylla subgroup (*H. heterophylla*, *H. naniflora*, and *H. minor*), which employ myrmecochory as a method for seed dispersal.

178
179 Ants appear to be a primary dispersal agent for the dwarf-flowered heartleaf (Gaddy 1986; Jones
180 et al. 2014). All diaspores of *Hexastylis naniflora* presented to ants (*Aphaenogaster ruidis*) were
181 quickly removed (Gaddy, 1986). This is not to say that they are not occasionally, or even
182 frequently, dispersed and/or pollinated by other means. Jones et al. (2014) suggests that the
183 pollination mechanism is facultative, benefiting from more than one method of
184 pollination/fertilization. Ants were the pollinators in a controlled experiment, and their data
185 supports that when outside molesting forces/pollinators (biotic and abiotic) were limited by their
186 caging procedure, the efficiency of pollination decreased by almost 50%, however, caged
187 flowers did produce seeds, indicating pollination occurred via some alternative method.

189 *Habitat*

190
191 Dwarf-flowered heartleaf appears to have a restricted range due to its habitat requirements. The
192 habitat where dwarf-flowered heartleaf exists is limited in size and scope due to a multitude of
193 factors including soil type, moisture availability, and slope aspect (Wagner 2013). This unique
194 combination of factors limits not only the range of dwarf-flowered heartleaf, but also the size of
195 a given population. With the limited range and size in populations, questions arise regarding
196 gene flow among populations. How much is occurring and how often does it occur? It is due, in
197 part, to narrow habitat requirements that conservation measures have been implemented for the
198 protection of the species. Any efforts made to protect this species must consider giving
199 protection to the available habitat.

200
201 Dwarf-flowered heartleaf occurs on piedmont uplands on acidic sandy-loam soils that are very
202 deep and moderately permeable (Gaddy 1981, 1987). Typical habitats for this species include
203 mesic to dry bluffs, slopes, or ravines in deciduous forests that are frequently associated with
204 *Kalmia latifolia* (Padgett 2004, Weakley 2015, USFWS 2015), or in moist soils adjacent to
205 creeks, streamheads, or along lakes and rivers. Plants have been observed to grow larger and
206 have more frequent flowering in floodplains along rivers, lakes, and streams (Newberry 1993).

Wagner (2013) conducted a habitat suitability study to quantify the habitat requirements for
 207 dwarf-flowered heartleaf, which may be used for helping identify the species when not in flower
 208 (relative to other *Hexastylis* species habitat preferences), find new populations, or identify
 209 suitable sites for transplants.
 210
 211
 212 *Soils*
 213
 214 The species appears to be restricted to Pacolet sandy loam, Madison gravelly sandy loam, and
 215 Musella fine sandy loam soils (Gaddy 1981, 1987). The species grows in acidic soils along bluffs
 216 and adjacent slopes, in boggy areas next to streams and creekheads, and along the slopes of
 217 nearby hillsides and ravines (Gaddy 1980, 1981). The plant is primarily found inhabiting north-
 218 to northwest-facing slopes, bluffs, and ravines in close proximity to creeks or streams. Within
 219 these areas exists the soil type required for *H. naniflora* to grow. It grows primarily on well-
 220 drained, sandy, acidic soils, and will not grow in heavy clay (Gaddy 1981).
 221
 222 The results of soil samples analyzed at the Clemson Soil Lab suggest that major differences in
 223 soil chemistry exist between the species in the *H. heterophylla* complex (Murrell et al. 2007).
 224 Statistical analysis of the soil samples showed that many of the basic elements were significantly
 225 different among the three species. Those significant differences occurred in Phosphorous (P),
 226 Potassium (K), Magnesium (Mg), Zinc (Zn), Manganese (Mn), (Na), Sodium, and Cation
 227 Exchange Capacity (CEC). Slightly significant differences were seen in Buffer pH (Bu pH), and
 228 Acidity.
 229
 230 Soil chemistry showed marked differences between the species in the complex (Murrell et al.
 231 2007). The results indicated that soil chemistry is very different between *H. naniflora* and *H.*
 232 *minor* localities. The results also show that *H. heterophylla* and *H. naniflora* are found in soils
 233 where the chemistry is more similar, but still showed significant differences. It would appear that
 234 differentiation in soil types could be used as a proxy for species delineation. The soil analysis
 235 also indicates that soils must be considered when trying to select sites for relocation of imperiled
 236 populations of *H. naniflora*.
 237

238 Thirteen population sites in North Carolina and South Carolina were examined using the
 239 Carolina Vegetation Survey (CVS) method to compare species richness between the three
 240 species of the *Hexastylis heterophylla* complex (Murrell et al. 2007). The analysis did not show
 241 statistically significant differences among the three species in the *H. heterophylla* complex.
 242 However, *H. naniflora* appears to have an association with three oak species that is lacking in the
 243 other two species in the complex. There are a number of oak species (*Q. coccinea*, *Q. prinus* (*Q. montana*), and *Q. velutina*), that tend to co-occur with only *H. naniflora*, but are not present with
 245 the other two species in the complex. This may be the result of some microbial need or specific
 246 soil nutrient required for those species to occur in the same habitat.

247 Five

250 There are little data on the response to fire by *Hexastylis naniflora*, however, prescribed burns
 251 have been conducted within the population at Cowpens National Battlefield in Cherokee County,
 252 SC. Preliminary data at this site and recent annual monitoring data of this population support the
 253 theory that moderate controlled burns do not negatively affect this population (Walker et al.
 254 2009). Additionally, a dormant season wildfire in Caldwell County did not show evidence of
 255 negative impacts to a population in Caldwell County (USFWS 2010). Fire suppression could be
 256 a hazard to *H. naniflora* by allowing fire intolerant, nonnative and invasive plants to thrive, as
 257 well as the accumulation of thick duff or leaf litter that may shade low growing species (Wagner
 258 2013).

259 Genetics

262 Analyses on ecology, morphology, soil chemistry, pollen, and molecular genetics have been
 263 evaluated for *Hexastylis naniflora* to determine the boundaries within the *Hexastylis*
 264 *heterophylla* complex, which consists of *H. heterophylla*, *H. minor*, and *H. naniflora* (Murrell
 265 2015, Wagner 2013, Niedenburger 2010, USFWS 2010, Murrell et al. 2007, Padgett 2004).
 266 These analyses support the continued recognition of these taxa as well-defined, discrete species.
 267 Scanning electron microscopy (SEM) consistently distinguished *H. naniflora* from other
 268 members of the *H. heterophylla* complex based on pollen microscopy. Principal Components

269 Analysis of floral characters and soil chemistry also consistently distinguished *H. naniflora* from
 270 *H. minor* and *H. heterophylla*. However, efforts to obtain consistently distinct banding patterns
 271 using Inter Simple Sequence Repeats (ISSRs) were unsuccessful at distinguishing *H. naniflora*
 272 from other members of this group (Murrell et al., 2007). These results were based upon an
 273 extremely small sample size (n=10 *H. naniflora* individuals), and therefore warrant further
 274 investigation.

275
 276 Field observations demonstrate that there are some populations of dwarf-flowered heartleaf with
 277 morphological characteristics that do not fit within the range of published values for key traits,
 278 overlapping with values for *H. heterophylla* or *H. minor* (Gaddy 1987, Murrell et al. 2007,
 279 USFWS 2010, Weakley 2015). These populations with overlap in key characteristics were the
 280 focus of a genetic analysis conducted at Appalachian State University (ASU) through funding
 281 provided by NCDOT (Murrell 2015). In some populations, floral characteristics are highly
 282 variable, which suggests the potential for hybridization or individuals with highly variable flower
 283 size and shape (Murrell 2015). Additionally, no vegetative characters were previously known to
 284 consistently distinguish *Hexastylis naniflora* from other close relatives. Given the difficulties
 285 with field identification of the species, particularly when not in flower, this study sought to
 286 develop a microsatellite library of molecular markers to resolve variation in populations of
 287 dwarf-flowered heartleaf and apply the markers to populations with highly variable characters, as
 288 identified by NCDOT biologists. The morphological and micromorphological information from
 289 those variable populations were compared to molecular results with morphological,
 290 micromorphological, and distributional data to determine genetic structure, biological boundaries,
 291 and placement of putative hybrids or intermediate populations of *H. naniflora* (Murrell 2015).

292
 293 The preliminary findings of this study suggest that populations in the southern range of dwarf-
 294 flowered heartleaf exhibit a more uniform genetic pattern, with some possible hybridization with
 295 *H. minor*. Populations in the northern part of the range appear to have hybridized with both *H.*
 296 *heterophylla* and *H. minor*, although there are still individuals with “pure” *H. naniflora*
 297 genotypes in the northern range (Murrell 2015). It is critical to note that although these data
 298 provide anecdotal evidence of hybridization with the *Hexastylis heterophylla* group, intraspecific
 299 variation may be caused by forces other than hybridization, such as convergent morphological

300 evolution (Dobzhansky 1937), or the species is in the process of speciation and this study shows
 301 a case of incomplete speciation (Murrell 2015), and/or other environmental factors are at play
 302 (Wagner 2013). On May 11, 2016, a meeting was held with USFWS, NCNHP, NCDOT, and
 303 ASU to discuss the status of *H. naniflora* and the current work being conducted among the
 304 agencies (Amoroso 2016). Based on discussions during this meeting, the results of this study
 305 reported by ASU to NCDOT in 2015 are preliminary. Dr. Matt Estep (ASU) provided additional
 306 preliminary results to NCNHP in May 2016, showing which populations were sampled, sample
 307 size, and percent of samples that show evidence of hybridization, and hybridizing with which
 308 species. ASU continues to work towards a more definitive explanation of the variation in the *H.*
 309 *heterophylla* complex (Murrell 2015, Amoroso 2016).

311 CHAPTER 3: SPECIES NEEDS

312
 313 For the purpose of this report, we define viability as the ability of the species to sustain
 314 populations in the wild over time. Species with greater numbers (redundancy) of healthy
 315 populations (resiliency), encompassing a broad array of ecological and genetic diversity in a
 316 spatial arrangement that maintains adequate gene flow (representation), are more likely to be
 317 viable. Using the Species Status Assessment framework, we describe the species' viability by
 318 characterizing the status of the species in terms of its resiliency, redundancy, and representation.

320 *Delineating Populations*

321
 322 As stated in the USFWS five-year review, many of those working with dwarf-flowered heartleaf
 323 have used the terms "sub site," "site," "location," "occurrence" (often, but not always, in
 324 reference to Natural Heritage Program Element Occurrence Records), and "population"
 325 interchangeably, while others have aggregated sites into populations according to subjective
 326 criteria which have never been explicitly defined. This has generated considerable discrepancies
 327 among sources with respect to the number of known populations within a given area (or across
 328 the species' range), to the extent that numbers are not comparable from one source to the next.
 329 The tendency, in the past, to treat each location as a separate population also artificially inflated
 330 the actual number of populations known.

331 The Natural Heritage Program collects information on occurrences of rare plants, animals,
 332 natural communities, and animal assemblages. Collectively, these are referred to as "elements of
 333 natural diversity" or simply as "elements." Locations of these elements are referred to as
 334 "element occurrences" (EO records). In recent years, NatureServe and its member Natural
 335 Heritage Programs have devised mapping standards to balance the need for fine-scale, highly
 336 site-specific EO records (required for monitoring and management) with the need to aggregate
 337 these records in meaningful units of conservation interest that may approximate biological
 338 populations (NatureServe 2002). Since USFWS does not maintain its own database of known
 339 locations of *Hexastylis naniflora*, it regards the NHP databases as the best repository for this
 340 information (USFWS 2010).

341 We delineate populations for the purposes of this SSA according to the NatureServe (2002)
 342 convention. Separation distances are a key component to delineating populations from EO
 343 records. For the dwarf-flowered heartleaf, we used the EO Data Standard which provides a
 344 Default Separation Distance of 1 km (~0.62 miles) for plant and animal elements that lack EO
 345 specifications, noting that situations involving dispersal barriers could involve even shorter
 346 distances. While gene flow declines over distance at different rates for different elements, the
 347 minimum default EO separation distance of 1 km has been accepted by the Network as the most
 348 suitable round-number metric-system approximation broadly applicable to many (but not all)
 349 situations. This results in several dwarf-flowered heartleaf populations being stand-alone EOs,
 350 as well as many populations being aggregates of several EOs.

351 *Population Resiliency*

352 For the dwarf-flowered heartleaf to maintain viability, its populations or some portion thereof
 353 must be resilient. Stochastic factors that have the potential to affect dwarf-flowered heartleaf
 354 include impacts to its habitat, particularly human development pressures, but also climate change
 355 and presence of invasive species. Other factors that influence the resiliency of dwarf-flowered
 356 heartleaf populations include abundance within populations, and habitat factors such as
 357 elevation, slope, aspect, and soil type. Influencing those factors are elements of dwarf-flowered

heartleaf ecology that determine whether populations can grow to maximize habitat occupancy, thereby increasing resiliency of populations. These factors and habitat elements are discussed below (Figure 3.1).

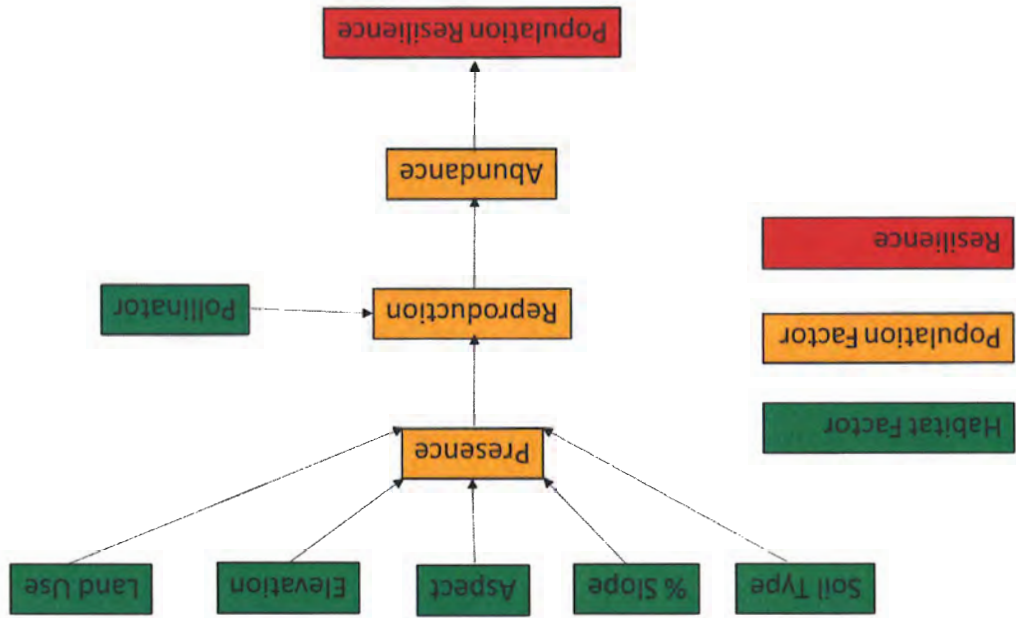


Figure 3.1. Conceptual diagram describing population and habitat factors influencing population resilience for dwarf-flowered heartleaf.

Habitat Factors: Slope, Aspect, Elevation, Soil, and Forest Type

A previous habitat suitability study attempted to quantify the habitat requirements for dwarf-flowered heartleaf (Wagner 2013). With this model in mind, and the input of species experts as to important habitat factors for the species, we used updated habitat data, as well as inclusion of updated EOs, to create a new habitat model to identify potential habitat throughout the species range. All source datasets and variables created are described in Appendix 3.

Source Data and Model Variables

Fifty-three, 10-digit hydrologic units (HUC) comprise the analysis extent (Figure 3.2). In North Carolina, it includes all 10-digit HUC that fall within the boundaries of 8-digit HUC with known occurrence of *Hexastylis naniflora*. In South Carolina, we also included all 10-digit HUC that

fell within the boundaries of 8-digit HUC with known occurrence of *Hexastylis naniflora*, but excluded the southern portions of the HUC-8 areas due to the boundaries being exceedingly large and far away from any known occurrences.

Hexastylis naniflora element occurrence data was obtained from the North Carolina Natural Heritage Program and the South Carolina Heritage Trust Program. Current populations of *Hexastylis naniflora* were identified by reviewing the last observed data in the database and excluding all populations that have not been observed since 2005 to remain consistent in our approach of assessing resiliency described previously. To represent these current population areas in Maxent, a raster cell center was retained for every 30 x 30 meter pixel that was situated within the current element occurrence data polygons.



Figure 3.2. Analysis extent of the habitat model for *Hexastylis naniflora*. Red line indicates Maxent analysis extent, blue lines are 8-digit HUC boundaries, black lines are 10-digit HUC boundaries. The orange line in the inset map indicates where the analysis extent is situated in North and South Carolina

Model Development

We used Maxent software (version 3.4.1) for species habitat modeling (Phillips et al., 2018). An initial single model Maxent run was done to determine which variables could be excluded due to limited percent contribution to the model. Any variable that contributed less than 1% to the single model run results was excluded in the final model. The following variables were excluded: landcover diversity, canopy height, SSURGO drainage class, SSURGO hydrologic group, aspect 9-class, slope 5-class, solar radiation, and maximum annual temperature. It is interesting to note that a previous habitat modelling effort (Wagner 2013) included aspect and slope, whereas the Maxent model excluded these variables. This does not mean these variables are not important components of dwarf-flowered heartleaf habitat, but rather these variables did not significantly improve the model. Also, landform data was included, and perhaps landform, which includes components of aspect and slope combined is a more meaningful variable than aspect or slope independently.

For the final model, a 10-run replicate Maxent model was created using cross-validation. For replicate models, the occurrence data is randomly split into a number of equal-sized groups called "folds", and separate models are created leaving out each fold in turn. The individual model runs are then averaged together to derive the final model.

Results

Figure 3.3 shows the model output. The minimum cutoff value (to determine if an area is considered potential habitat for a species) of 0.39 was determined by using the average 10th percentile training presence. The 10th percentile training presence uses the suitability threshold associated with the presence record that occurs at the 10th percentile of presence records (Phillips 2018). This value excludes some of the outlier population areas in the Maxent

425 predictions to focus on the typical habitat conditions for this species. The total area ranked
 426 greater than 0.39 in the Maxent model was just 6.00% of the total analysis area (Table 3.1).

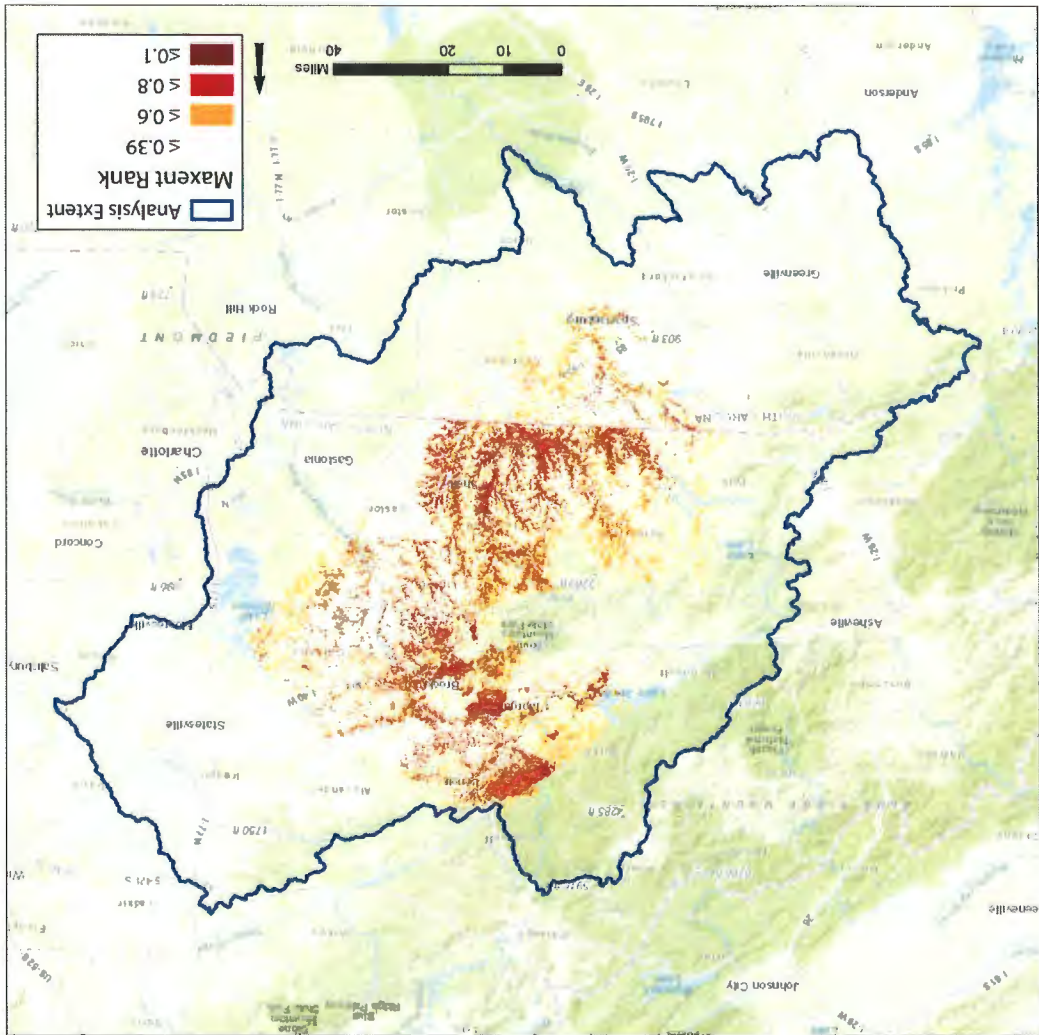


Figure 3.3. Maxent model output map

Table 3.1-Area estimates of the Maxent model

Maxent Score	Acres	Square Miles	Percent of Total
0.39 and greater	302,834.13	473.18	6.02%
0.6 and greater	128,273.52	200.43	2.55%
0.8 and greater	22,115.97	34.56	0.44%

432 The average area-under-curve (AUC) score for the replicate Maxent model is 0.86. The AUC is
 433 calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1
 434 and may be interpreted as a single test statistic that assesses model performance, indicating the
 435 ability of the model to correctly classify the occurrence data used. The model performed well in
 436 its predictions, with a mean AUC of 0.86 (AUC value of 0.5 is no better than random; $AUC < 0.5$
 437 is worse than random; $AUC > 0.5$ is greater predictive power than random; Baldwin 2009).

438 The Maxent output supplies estimates of the relative contributions of the environmental variables
 439 to the Maxent model (Table 3.2). SSURGO map unit key) is the top contributing variable. One

440 hundred and thirty-five individual soil types are present within the polygon boundaries of the
 441 *Hexastylis naniflora* element occurrences. Many of these individual soil types are part of soil
 442 complexes and are separated by things such as percent slope, erosion, how stony/rocky, and
 443 amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25
 444 to 60 percent slopes, very stony (14.1% of total). However, collectively the Meadowfield soils
 445 only comprised 14.3% of all soils). The individual Pacolet soil types were very common and
 446 collectively comprise 36% of all soil types present. Woolwine, Rion, and Fairview soils were
 447 also collectively common, comprising 10.4%, 9.7%, and 8.8% of all soils present respectively.

Table 3.2. Percent contribution of the environmental variables

Environmental Variable	Percent Contribution
SSURGO map unit key	23.5%
Minimum Annual Temperature	17.8%
Average Annual Precipitation	15.7%
Landcover	12.9%
Landcover Majority	12.0%
Landcover Hexastylis Grouping	5.4%
Geomorphons	4.9%
Elevation	4.6%
Canopy Cover	3.2%

SSURGO is the
 what is the
 SSURGO? Please explain

can you explain what does the
 variable describe

452 The minimum annual average temperature range in the analysis extent is 39 – 51 degrees Fahrenheit. The majority of the *Hexastylis naniflora* element occurrences (89%) are found at the 47 and 48 degrees. The average annual precipitation range in the analysis extent is 42 – 81 inches per year. The majority of the *Hexastylis naniflora* element occurrences (82%) are found in the 47 – 49 inches per year range.

457

458 Piedmont forested landscape habitats dominate the land area of the element occurrences.

459 Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier (53%), Southern Piedmont Mesic Forest (9%), Southern Piedmont Dry Oak-Pine Forest (5.2%), Southern Piedmont Small Floodplain and Riparian Forest (4.4%), and collectively comprise 71% of the element occurrences area. Evergreen Plantation or Managed Pine (9%), Harvested Forest (7.2%), Developed, Open Space (5%), Pasture/Hay (2.1%) collectively comprise 22% of the total element occurrence area. The remaining 6 percent of element occurrence area is comprised of a mix of 14 other natural and disturbed landscape classes, but each at small percentages.

466 The landscape majority classification scheme reduces the total number of landscape classes present in the analysis extent from 23 to 11. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landscape class (58%). However disturbed categories are increased in area (sum total of 35%). Evergreen plantation or managed pine (12%) and Pasture/Hay (12%) are the only other categories that have at least 10% or greater area. The increase in disturbed landscape area representation in the landscape majority layer suggests that many *Hexastylis naniflora* population areas are situated in areas impacted by disturbed landscape. This is likely due to urban encroachment and increasing fragmentation of habitats.

473 The landscape *Hexastylis naniflora* grouping reveals the amount of disturbance present in *Hexastylis naniflora* population areas. Landscape classes grouped as disturbed comprises 27% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, pasture/hay 12%, and hardwood forest 2%. Open water, evergreen and barren landscape groupings are all at less than 1% each.

480 Geomorphons revealed that the majority of *Hexastylis naniflora* element occurrence areas are situated in concave landforms. Geomorphon categories hollow (13%), valley (46%), and

How can we make out survey data? surveys required of development have been used in the surveys is where all or that this

depression (10%) collectively comprise 69% of all *Hexastylis naniflora* population areas. Flat

landforms comprise 15.5% of the area and convex landforms the remaining 15.5%.

Within the analysis extent, the range of elevation present is 335 – 5,265 feet. For *Hexastylis*

naniflora, the prime elevation range is from 666 – 908 feet (53% of total element occurrence

area). A lesser elevation range is present from 935 – 1,184 (37% of total element occurrence

area).

Canopy cover for the *Hexastylis naniflora* populations are dominated by Tree Cover 70-80%

(20.2%) and Tree Cover 80-90% (63.9%). The rest of the canopy cover categories are 2% or

less.

We performed a Kruskal-Wallis 1-way non-parametric Analysis of Variance (ANOVA) to

investigate the relationship between Maxent scores and current resilience of populations (Table

3.3). There are significant differences in the average Maxent scores between the four resilience

categories ($p = 0.04$) and the mean Maxent score increases as population resilience increases

from low to very high. The model gives us some predictive ability regarding habitat suitability

where higher Maxent scores, on average, result in higher population resilience.

So what does this mean? Hee we strongly suggest that higher resiliency are more resilient? Please dumb it down a little.

Table 3.3 Results of the Kruskal-Wallis 1-way non-parametric ANOVA investigating relationships between Maxent scores and current resilience groups for dwarf-flowered heartleaf.

Groups	Count	Mean Rank
low	13	30.7
moderate	25	30.7
high	5	42.8
very high	28	45.7

Source of Variation	SS	df	MS	F	P-value
Between Groups	4375.7	4	1093.92	2.65	0.0404

504	Total	32412.0	72
505			
506	<i>Reproduction and Presence of Pollinators</i>		
507			
508	The pollination of <i>Hexastylis</i> has not been well studied but the genus is thought to be pollinated		
509	by insects including flies, wasps, and thrips (Otte 1977). Additionally, Lengyel et al. (2010)		
510	described how, within the family Aristotlochiaceae, more than 50% of the plant lineage is		
511	myrmecochorous (seed dispersal via ants). This supports Gaddy's work (1986), which found		
512	three species within the Hexastylis Heterophylla subgroup (<i>H. heterophylla</i> , <i>H. naniflora</i> , and <i>H.</i>		
513	<i>minor</i>), which employ myrmecochory as a method for seed dispersal.		
514			
515	Because the flower for this species is oftentimes partially or completely covered with soil and		
516	leaf litter, possibly inhibiting pollinator activity (Gonzalez 1972), there is still uncertainty in the		
517	pollination mechanism for dwarf-flowered heartleaf. Otte (1977) suggests that a variety of		
518	possible pollinators reside in this leaf litter, however, the calyx opening is considered to be far		
519	too small for efficient pollinating (Gaddy 1981). There are, however, invertebrates within this		
520	proposed size limit that could theoretically act as pollinators. It is possible that the species		
521	employs self-pollination, with or without a vector, or that cross-pollination occurs by a number		
522	of invertebrates. Jones et al. (2014) investigated pollination of dwarf-flowered heartleaf under a		
523	manipulative experimental design, and found that while insects may play a significant role in		
524	pollination, even without them, flowers managed to produce a partial seed set. However, two		
525	points need to be considered here. First, although flowers managed to produce seeds in the		
526	absence of insect pollinators, the efficiency of pollination decreased by almost 50%. Also, even		
527	if successful pollination occurs in the absence of insect vectors, the dispersal of plants amongst		
528	populations would be limited, and could result in decreased resilience due to genetic concerns		
529	such as limited gene flow and issues associated with potential inbreeding depression.		
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531	<i>Abundance</i>		
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532 The influence of stochastic variation in demographic (reproductive and mortality) rates is much
 533 higher for small populations than large ones. Stochastic variation in demographic rates causes
 534 small populations to fluctuate randomly in size. In general, the smaller the population, the greater
 535 the probability that fluctuations will lead to extinction. There are also genetic concerns with
 536 small populations, including reduced availability of compatible mates, genetic drift, and
 537 inbreeding depression. Small populations of dwarf-flowered heartleaf have low resilience,
 538 leaving them particularly vulnerable to stochastic events.

540 As of 2016, the combined databases of the NCNHP and SCDNR contain 239 Element
 541 Occurrence Records (EORs) for *H. naniflora* (NCNHP 2016, SCDNR 2016). These EORs depict
 542 roughly 113 locations which are sufficiently geographically distinct to be regarded as proxies for
 543 populations of the species (See *Delineating Populations*). Thus, the total number of populations
 544 has increased more than four-fold (from 24 to 113) since the species was listed in 1989.

546 At this time, the largest known populations have been monitored by NCNHP and NCDOT. The
 547 estimates for entire populations are based on a consistent monitoring methodology developed by
 548 NCDOT, USFWS, and NCNHP with monitoring plots representing roughly 10% of a population.
 549 Populations were delineated to get a more accurate boundary and size of the area occupied. All
 550 rosettes are counted annually in each monitoring plot to estimate an extrapolated population size,
 551 based on the number and density in the plots. As a result of these efforts, better estimates of
 552 population sizes for the largest known populations are available, compared to when the last five-
 553 year review was completed in 2010 (Robinson and Padgett 2016).

555 The 113 EORs have been estimated to contain anywhere from a single rosette to over 100,000
 556 rosettes. Appendix 1 was created by NCNHP (2016) to replicate the same format and population
 557 data as Table B2 of the most recent USFWS five-year review of *H. naniflora* (USFWS 2010), for
 558 comparison of changes since 2010, and summarizes the largest occurrences of *H. naniflora*, with
 559 the size of the population based on the number of rosettes it was last estimated to contain. The
 560 number of populations estimated to contain over 1,000 rosettes is 26. This is approximately 23%

562 of the total known populations and many of these populations contain well over 1,000
 563 individuals.
 564
 565 There are, however, 13 populations (12% of all known) that are simply known to be extant, with
 566 no available estimate of population size (NCNHP 2016, SCDNR 2016). If the most recent
 567 population estimates for each EOR are compiled across years of observation, the 13 populations
 568 could conservatively be estimated to contain a collective total of more than 300,000 rosettes
 569 (NCNHP 2016, SCDNR 2016).
 570
 571 Population Trends
 572

573 Although abundance is critical in assessing the resilience of dwarf-flowered heartleaf, trends in
 574 population growth can also be informative. Long-term growth trends are typically defined as the
 575 degree of change in population size over 200 years, whereas short-term growth is typically
 576 measured as that degree of change over a 10 year period. We lack a robust data set to assess
 577 trends at either of these time scales. However, from 2012-2016, NCNHP conducted systematic
 578 annual surveys of thirteen of the largest populations across the range.

579
 580 Based on the results of the five-year monitoring efforts completed in 2016, nine out of thirteen
 581 populations remain stable during the five years of data collection (Robinson and Padgett 2016).
 582 The largest known population, Broad River: Henson's Creek, Brice, & Sandy Mush Outcrop in
 583 Rutherford County, NC, is estimated to have over 100,000 rosettes (Robinson and Padgett 2016).
 584 This large population consists of many scattered subpopulations on private property; two of the
 585 subpopulations are protected as a Registered Heritage Area, although Registry is a non-binding
 586 agreement with landowners that can be cancelled at any time (NCNHP 2018).

587
 588 Two of the thirteen populations increased in numbers from 2012-2016: Cliffside Steam Station
 589 and Broad River: Floyds Creek, Long Branch. The Cliffside Steam Station is protected with a
 590 voluntary agreement with Duke Energy and was estimated to contain over 39,000 rosettes in
 591 2016. The Broad River: Floyds Creek, Long Branch population is not at all protected, but was
 592 last estimated to consist of over 12,000 individuals in 2016 (Robinson and Padgett 2016).

Based on the results of recent surveys and a review of all known populations of *Hexastylis naniflora*, the overall trend over approximately 30 years is estimated to be declining 10-30%. This is estimated by a combination of documented declines of some populations, while many others appear to be remaining relatively stable, and some have increased.

Chapter 4: CURRENT CONDITIONS

Below we assess current resilience, representation, and redundancy as they relate to population and habitat factors known to be important for species viability. Based off of recent reports (Robinson and Padgett 2016; Robinson 2016), the species consists of 119 populations distributed across 12 counties in North Carolina and South Carolina. Populations are composed of both multiple EOs and stand-alone EO records. Recent genetic research discussed in Chapter 2, suggests that dwarf-flowered heartleaf, as originally described, is found in the southern portion of its presumed range based on current EO locations, and the northern portion could be a currently undescribed species (Figure 4.1; Estep pers. Comm. 2018). The genetic analysis to support this is complete, but a review of the morphology is ongoing and a new species has not yet been described (Estep pers. Comm. 2018). For the purpose of this SSA, we assume all EO detections are *H. naniflora*, and represent the best currently available scientific data.

Inconsistent with p. 27 (113)
Which says 119 pop's.

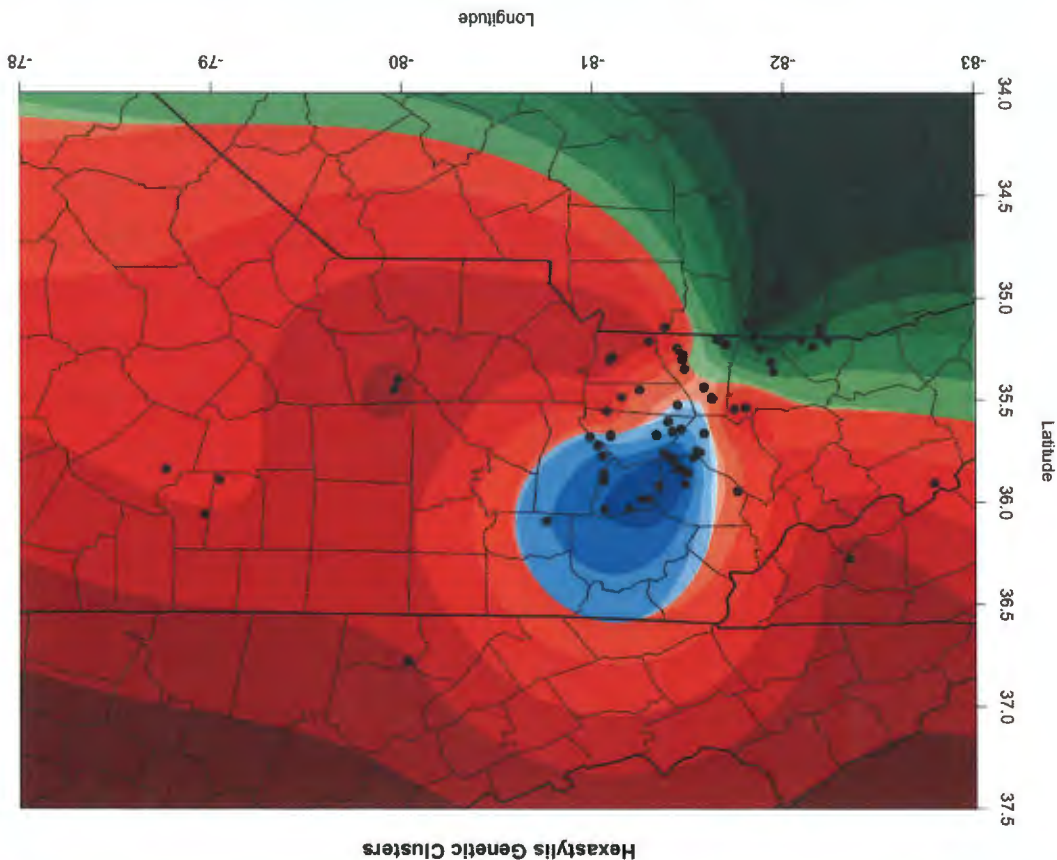


Figure 4.1. Recent genetic analyses detailing clustering of the genus *Hexastylis*. Black dots represent GIS locations of individual plants included in the genetic analysis. Green areas represent "true" *H. naniflora*; Blue represents a possible new species; Red represents other species in the genus (*H. minor*, *H. heterophylla*, etc.).

Current Population Resilience

Categorizing Resilience

For the purposes of this SSA, we use population size as the main driver of population resilience. The unit of measurement for population size in this species is a "clump" (rosette). As discussed previously, populations in North Carolina were delineated by NCNHP, whereas the Service defined populations in South Carolina. These delineations were based off of NatureServe criteria such as EO separation distance and intervening landscape matrix. EO data included a wide range

628 of years since the species was last observed at a given location (1964-2017), so although recent
629 reports suggest the species consists of 113 populations, some of that data is fairly outdated. For
630 the purposes of this SSA, we only used EOs that were observed since 2005. We did this for
631 several reasons. First, we did not want to go back too far and assume a population was still
632 present. Second, we wanted to be consistent in what we considered "current" for both
633 categorizing resilience and use in the habitat model (discussed later). Also, experts concurred
634 that records as old as 12 years are still likely to persist. Finally, there was a natural break in the
635 data at the year 2005, coinciding with the year the last five-year review was initiated, where the
636 number of EOs dropped off significantly in the years 2004 and earlier. It is important to note
637 that many of the populations that we excluded from our analysis may still persist on the
638 landscape. In fact, many EOs for this species have persisted for decades, despite not having
639 intervening surveys to confirm their persistence.

640

641 Based on the criteria (excluding EOs prior to 2005), there are currently 78 populations
642 distributed across the range of dwarf-flowered heartleaf, although this may be an underestimate
643 as discussed above.

644

645 To determine overall resilience for populations, we used EO viability ranks and expert opinion to
646 bin population size classes into corresponding resilience categories. EO viability ranks for the
647 species include excellent, good, fair, poor, extant, historical, and failed to find. The primary
648 factor in determining these ranks is EO size (as quantified by number of clumps). Condition of
649 habitat (vegetation community and structure) and landscape context (extent of suitable habitat
650 and physical factors) are also incorporated secondarily. Appendix 2 shows the NCNHP EO rank
651 specifications for dwarf-flowered heartleaf. The EO rank specifications suggest good-excellent
652 viability for populations consisting of at least 500 individuals, given there is sufficient high
653 quality habitat; fair viability for populations consisting of 100-500 individuals, depending on
654 habitat conditions; poor viability for populations consisting of less than 100 individuals. Recent
655 reports (Robinson 2016; Robinson and Padgett 2016) focus monitoring studies on populations
656 with greater than 1,000 individuals, populations that are assumed to be very viable. Because we
657 do not have habitat level information for every population we assessed, we synthesized all of the
658 above population size information and created four resilience categories as follows:

- Very high—populations with >1,000 individuals; very high probability of persistence for 20-30 years at or above the current population size.
- High—populations with 500-1,000 individuals; moderate-high probability of persistence for 20-30 years at or above the current population size.
- Moderate—populations with 100-500 individuals; low probability of persistence for 20-30 years at or above the current population size.
- Low—populations with <100 individuals; low probability of persistence for 20-30 years at or above the current population size, and moderate-high probability of extirpation.

Occupancy and Abundance

There are 78 populations of dwarf-flowered heartleaf that have been observed since 2005 (Table 4.1), and resilience of these populations is as follows: 28 (very high); 5 (high); 26 (moderate); 19 (low). Table 4.2 shows the contribution of each resilience category as follows: 36% (very high); 7% (high); 34% (moderate); 23% (low). When looking at cumulative percentages of resilience, it is interesting to note that 77% of all of the populations are classified as moderate to very high resilience (Table 4.2).

Table 4.1. Current populations of dwarf-flowered heartleaf and associated resilience across the species range. Abundance and last observation date based on Natural Heritage Program data (2018).

Site Name	State	County	Last Observed	Total plants	Resilience
Glade Creek, Alex County	NC	Alexander	2017	>1000	very high
Catawba River: Hoyle Crk-Micol Crk	NC	Burke	2013	>1000	very high
Island Creek Heath Bluff	NC	Burke	2016	>1000	very high
Gunpowder Creek: South of Hudson	NC	Caldwell	2012	>1000	very high
Peaked Top Rare Plant Site/Foothills Landfill	NC	Caldwell	2014	>1000	very high
Jacob Fork West Corridor	NC	Catawba	2012	>1000	very high
Murrays Mill/Upper Balls Creek	NC	Catawba	2013	>1000	very high
NC DOT TIP: R-2824	NC	Catawba	2015	>1000	very high
South Fork Catawba R: Clark Crk, Miller Br, Cata Mem Hos	NC	Catawba	2013	>1000	very high
Cowpens NBF - Site 1	SC	Cherokee	2016	>1000	very high

Site Name	State	County	Last Observed	Total plants	Resilience
Cliffside Steam Station	NC	Cleveland/Rutherford	2016	>1000	very high
Broad River/Sandy Run NA	NC	Cleveland	2012	>1000	very high
Broad River: Brushy Creek	NC	Cleveland	2016	>1000	very high
Buffalo Creek: Kings Mountain Res	NC	Cleveland	2016	>1000	very high
Buffalo Creek: Tributaries N and S of SR 2047	NC	Cleveland	2012	>1000	very high
Rhyme Conservation Preserve	NC	Lincoln	2016	>1000	very high
Mill Creek Forest and Seep	NC	Polk	2016	>1000	very high
New Hope Springhead Swamp	NC	Polk	2016	>1000	very high
Big Horse Creek Rare Plant Site	NC	Rutherford	2015	>1000	very high
Broad River: Floyds Creek	NC	Rutherford	2016	>1000	very high
Davenport Road/Mountain View Rare Plant Site	NC	Rutherford	2016	>1000	very high
Facebook Site	NC	Rutherford	2016	>1000	very high
Floyds Creek Tributary Rare Plant Site	NC	Rutherford	2012	>1000	very high
New Bethel Rare Plant Site	NC	Rutherford	2015	>1000	very high
Richardson Creek trib above Toms Lake	NC	Rutherford	2016	>1000	very high
DNR Peters Creek Heritage Preserve	SC	Spartanburg	2016	>1000	very high
Taylor Blalock Res	SC	Spartanburg	2016	>1000	very high
Leepers Creek Heartleaf Site	NC	Lincoln	2006	>1000	very high
Little Gunpowder Creek Rare Plant Site 1	NC	Caldwell	2015	500-1000	high
Little Gunpowder Creek Rare Plant Site 2	NC	Caldwell	2015	500-1000	high
Northern Catawba County	NC	Catawba	2017	500-1000	high
Rock Barn Solar Farm	NC	Catawba	2010-2011	500-1000	high
Buffalo Creek Rare Plant Site	NC	Cleveland	2012	500-1000	high
Third Creek Rare Plant Site	NC	Alexander	2010	100-500	moderate
Hickory Area	NC	Burke/Catawba/Caldwell	2016	100-500	moderate
Burke County - Drowning Creek UT	NC	Burke	2017	100-500	moderate
Simms Hill/Little River Uplands	NC	Burke	2015	100-500	moderate
Smith Cliff/Henry Fork River	NC	Burke	2015	100-500	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork Catawba River Jacobs Fork and Camp Creek	NC	Catawba	2016	100-500	moderate
NCDOT TIP R-2824	NC	Catawba	2015	100-500	moderate
South Fork Catawba River, Henry Fork	NC	Catawba	2007	100-500	moderate
Broad River/Sandy Run NA	NC	Cleveland	2012	100-500	moderate
Brushy Creek Headwaters	NC	Cleveland	2014	100-500	moderate
First Broad River: Crooked Run Creek	NC	Cleveland	2010	100-500	moderate
No Business Creek, Boyd Tract	NC	Cleveland	2007	100-500	moderate

Site Name	State	County	Last Observed	Total plants	Resilience
West Shelby Mesic Slope	NC	Cleveland	2016	100-500	moderate
UT of Kings Mountain Res	NC	Gaston	2012	100-500	moderate
Buffalo Shoals Creek	NC	Iredell	2014	100-500	moderate
Cat Square Heartleaf Forest	NC	Lincoln	2012	100-500	moderate
Collinsville (Hughes) Creek Slopes	NC	Polk	2016	100-500	moderate
Fox Knoll Farm	NC	Polk	2016	100-500	moderate
Forest City: Adj to Isothermal CC	NC	Rutherford	2010	100-500	moderate
Jonas Road Rare Plant Site	NC	Rutherford	2014	100-500	moderate
Knob Creek NA	NC	Cleveland	2005	100-500	moderate
Buffalo Creek	NC	Cleveland	2005	100-500	moderate
Kross Keys NA	NC	Polk	2005	100-500	moderate
Catawba River: North Fork	NC	Catawba	2005	100-500	moderate
Catawba River: Lake James	NC	Burke	2006	100-500	moderate
Hogpen Branch Transplant Site	NC	Rutherford	2005	100-500	moderate
NCDOT T1P R-3603A	NC	Alexander	2017	<100	low
South Mountains Pleasant Grove	NC	Burke	2016	<100	low
Uplands	NC	Burke	2016	<100	low
Gunpowder Creek	NC	Caldwell	2012	<100	low
Killian Crossroads	NC	Catawba	2010	<100	low
Pott Creek	NC	Catawba	2012	<100	low
Beaverdam Ck at First Broad River	NC	Cleveland	2011	<100	low
Buffalo Creek: Potts Creek	NC	Cleveland	2012	<100	low
Buffalo Creek: Ravine	NC	Cleveland	2007	<100	low
Hickory Creek - UT (Shelby High School)	NC	Cleveland	2016	<100	low
Boulder Creek Subdivision - Jordan Road	SC	Greenville	2016	<100	low
Gateway Elementary School	SC	Greenville	2017	<100	low
Fanjoy Road Site	NC	Iredell	2015	<100	low
Levan Family Farm	NC	Iredell	2013	<100	low
Lincoln County, SR-1314	NC	Lincoln	2014	<100	low
Northeast Lincoln: UT Walker Branch	NC	Lincoln	2009	<100	low
Sandy Spring Church Springhead Swamp	NC	Polk	2005	<100	low
First Broad River: Hickory Creek	NC	Cleveland	2006	<100	low
Smith Cliff/Henry Fork River	NC	Burke	2005	<100	low
First Broad River: Beaverdam Creek Tribs	NC	Cleveland	2006	<100	low

Table 4.2. Population resilience categories by county for dwarf-flowered heartleaf.

County	Very High	High	Moderate	Low	Totals
Alexander	1		1	1	3
Burke/Catawba/Caldwell			1		1
Burke	2		4	2	8
Caldwell	2	2		1	5
Catawba	4	2	4	2	12

Cherokee	1				
Cleveland/Rutherford	1				1
Cleveland	4	1	7	6	18
Gaston			1		1
Greenville				2	2
Iredell			1	2	3
Lincoln	2		1	2	5
Polk	2		3	1	6
Rutherford	7		3		10
Spartanburg	2				2
Totals	28	5	26	19	78
% of total	36	7	34	23	100
Cumulative %	40	43	77	100	--

Population Trends

Although we lack an adequate past time series of abundance data for all populations to estimate growth rates or population trends, NCNHP conducted surveys of thirteen of the largest populations across the range of the species from 2012-2016. Table 4.3 shows the results of all of these surveys. Two populations show an increasing trend, nine show a stable trend, and two show a decreasing trend.

Table 4.3. Summary of population trends over 5 years of monitoring data for 13 of the largest populations of dwarf-flowered heartleaf across its range (from: Robinson and Padgett 2016).

Trend	Survey	Site	2016 estimated number of plants (Rosettes)	2016 area occupied (Acres)
Increasing	NCNHP	Cliffside Steam Station (EO 276)	39,535	52
	NCNHP	Broad River: Floyds Creek, Long Branch (EO 177)	12,687	5.67
Stable	NCNHP	Island Creek Bluff/Love Lady Site (EO 029)	50,481	61.76
	NCNHP	Rhyme Preserve (EO 302)	19,873	22.43
	NCNHP	Mills Creek Forest and Seep (EO 023)	1,733	1.39
	NCNHP	New Hope Springhead Swamp (EO 125)	12,235	5.03

722 has the potential to negatively influence population resiliency outside of normal environmental
723 and demographic stochasticity. Disturbances often act quickly, like hurricanes, and often with
724 devastating effects, however they can also occur over long periods of time. A disturbance that
725 occurs as a relatively discrete event in time is referred to as a "pulse" disturbance, while more
726 gradual or cumulative pressures on a system are referred to as "press" disturbance. Both types of
727 disturbances are part of the natural variability of dwarf-flowered heartleaf ecological systems,
728 and must be considered when assessing redundancy. While there is certainly a variety of
729 potential pulse disturbances for the species (timber harvest, hydrological alterations, road and
730 right-of-way construction), the primary potential catastrophic disturbances are press disturbances
731 from long term climate change, which have great potential to affect ecosystem processes and
732 communities by altering the underlying abiotic conditions (DeWan et al. 2010).

733

734 As stated previously, there are 78 populations of dwarf-flowered heartleaf that have been
735 observed since 2005 (Table 4.1), and resilience of these populations is as follows: 28 (very high);
736 5 (high); 26 (moderate); 19 (low). The populations are spread across the range, although a
737 majority occur in North Carolina. Although, there appears to be adequate redundancy within the
738 range of dwarf-flowered heartleaf to withstand the impacts of localized press catastrophic
739 disturbances, the species range is very small, making it potentially vulnerable to long-term
740 catastrophic events, such as climate change.

741

742 **CHAPTER 5: INFLUENCES ON VIABILITY**

743

744 *Hexastylis naniflora* populations occur in rapidly growing urban areas with expanding suburbs of
745 Charlotte, NC, to the east; Hickory, NC, to the north; and Greenville and Spartanburg, SC, to the
746 south. At the time of listing, it was determined that the species was most threatened by habitat
747 loss due to the conversion of land to residential, commercial, and industrial use in these areas.
748 In addition to threats associated with residential, commercial, and industrial development, other
749 documented threats include habitat loss from land conversion to agricultural use, timber harvest,
750 hydrological alterations from the damming of ponds, impacts from grazing cattle, ORV damage,
751 trampling from foot traffic, invasive species, highway or road improvements, and erosion or

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Caldwell	83,919	86,723	88,689	91,126	92,870
Catawba	157,424	159,799	162,175	164,549	166,447
Cleveland	98,862	99,685	100,004	100,128	100,170
Gaston	221,112	227,667	237,344	245,276	252,388
Iredell	179,740	195,623	211,501	227,383	240,088
Lincoln	84,494	91,034	96,865	103,069	107,858
Polk	21,273	21,823	22,288	22,681	22,955
Rutherford	67,880	68,154	68,283	68,341	68,368



Table 5.2- Human population projections for South Carolina counties within the range of dwarf-flowered heartleaf. Source: U.S. Census Bureau, 2000 Census and 2007 Population Estimates. Population projections calculated by South Carolina Budget and Control Board, Office of Research and Statistics.

County	2020	2025	2030	2035
Cherokee	61,760	64,760	67,350	70,170

back to 113 → I thought it was at 78

809 SCNDR 2010). Another 16 populations have been specifically reported to be threatened by one or more of these same sources. Therefore, threats have either occurred or are reasonably

810 foreseeable within 42 of the 113 populations (corresponding to 37% of all known populations).

811 Of these 42 populations, all or portions of 22 (50%) had been adversely impacted by activities

812 requiring ESA Section 7 consultation with the USFWS. The fact that nearly 20% of all known

813 populations had been subject to formal Section 7 consultation illustrates the threats faced by the

814 species.

815 In the same 2010 review, the most recurrent source of habitat destruction, and certainly the most common trigger for Section 7 consultations involving *H. naniflora* is road and bridge

816 improvement projects. Ten of the 27 largest populations (containing more than 1,000 rosettes)

817 have been the subject of Section 7 consultations between the USFWS and the NCDOT.

818 Collectively, these projects have adversely impacted or are currently expected to impact some

819 22,135 rosettes. In most cases the Section 7 process has resulted in avoidance or minimization of

820 adverse effects through relocation of plants and/or commitments of on-site protection to those

821 plants remaining (post-construction) within NCDOT right-of-way (ROW).

822 Other forms of economic development have also resulted in the destruction or modification of habitats occupied by *H. naniflora*; in many cases, these activities have also required Section 7

823 consultations with the USFWS. Examples of these activities include the maintenance or

824 expansion of hydroelectric and drinking water reservoirs, construction of an industrial

825 development complex, and maintenance activities (in compliance with Federal Aviation

826 Administration standards) at a regional airport. Collectively, these activities have involved the

827 loss or relocation of several thousand rosettes.

828 Blalock Reservoir in Spartanburg County, South Carolina was once estimated to contain the

829 largest population of *H. naniflora*, with over 11,000 rosettes reported here in 1997 (JL&G, 1998).

830 This population was the subject of a section 7 consultation as a result of a proposal to raise the

831 elevation of Blalock Reservoir, which provides water supply storage to Spartanburg County and

832 the City of Spartanburg (USFWS, 2001). Approximately one-third of this population was

833 directly threatened by inundation, and the Federal agency committed to the relocation of some

870 populations are secured against habitat conversion, but lack designated managers with the
 871 technical expertise and available resources (funding and personnel) to address this threat.

875 *Climate Change*

876
 877 There is a growing concern that climate change may lead to increased frequency of severe storms
 878 and droughts (McLaughlin *et al.* 2002, p. 6074; Golladay *et al.* 2004, p. 504; Cook *et al.* 2004, p.
 879 1015). Because typical habitats for this species include moist soils adjacent to creeks,
 880 streamheads, or along lakes and rivers, and plants have been observed to grow larger and have
 881 more frequent flowering in floodplains along rivers, lakes, and streams (Newberry 1993),
 882 specific effects of climate change to the dwarf-flowered heartleaf are likely related to changes in
 883 soil moisture associated with potential increases in drought.

884
 885 Warming in the Southeast is expected to be greatest in the summer (NCCV 2016) which is
 886 predicted to increase drought frequency, while annual mean precipitation is expected to increase
 887 slightly, leading to increased flooding events (IPCC 2013, p.7; NCCV 2016). Changes in
 888 climate may affect ecosystem processes and communities by altering the abiotic conditions
 889 experienced by biotic assemblages resulting in potential effects on community composition and
 890 individual species interactions (DeWan *et al.* 2010, p.7).

891
 892 Despite the recognition of potential climate effects on ecosystem processes, there is uncertainty
 893 about what the exact climate future for the Southeastern US will be and how the ecosystems and
 894 species in this region will respond. Although climate change was not a factor leading to the
 895 original listing of the species, it should be recognized that the greatest threat from climate change
 896 may come from synergistic effects. That is, factors associated with a changing climate may act as
 897 risk multipliers by increasing the risk and severity of more imminent threats. As a result, impacts
 898 from rapid urbanization in the region might be exacerbated under even a mild to moderate
 899 climate future.

900

901 Regardless of a pessimistic, optimistic, or status quo climate future, the following systematic changes are expected to be realized to varying degrees in the Southeastern US (IPCC 2013):

- 902
- 903
- 904 • More frequent drought
- 905 • More extreme heat (resulting in increases in air and water temperatures, Figure 5-3)
- 906 • Increased heavy precipitation events (e.g., flooding)
- 907 • More intense storms (e.g., frequency of major hurricanes increases)
- 908 • Rising sea level and accompanying storm surge
- 909

910 In recent years, the Southeast has experienced moderate to severe droughts that many observers have implicated in population declines and poor transplant survivorship (NCNHP, 2010). A

911 wildfire, presumably brought on or at least exacerbated by drought conditions, burned portions

912 of one of the largest known populations in 2009 (Foothills Landfill in Caldwell County; Golder

913 and Associates, 2009). Accelerated climate change is expected to increase the frequency and

914 extent of drought conditions across the southeast (Karl, et al. 2009). The extent to which these

915 climate changes will significantly affect populations of dwarf-flowered heartleaf is currently

916 unknown.

917

918

919 Appendices 4a and 4b gives summary reports on historical and future predicted climate

920 parameters from the USGS National Climate Change Viewer for both North Carolina and South

921 Carolina. As discussed above, the trend for these States is consistent with the general trend in

922 the Southeast: more frequent drought, more extreme heat, and increased precipitation events. If

923 these predictions hold true, dwarf-flowered heartleaf habitat would likely be impacted through

924 increased evaporative rates and decreased soil moisture (Appendices 4a and 4b), increased

925 potential for catastrophic wildfire events, as well as potential disruption of stream bank

926 morphology through increased flooding events. Our habitat model indicates a preferred

927 temperature and precipitation range, indicating that the species would be sensitive to a changing

928 climate.

929

930

931

so how do
they respond to
fire? Fire
can be good for
eliminating
competition +
fertilizing the
soil.

Chapter 6: FUTURE CONDITION

Future Considerations

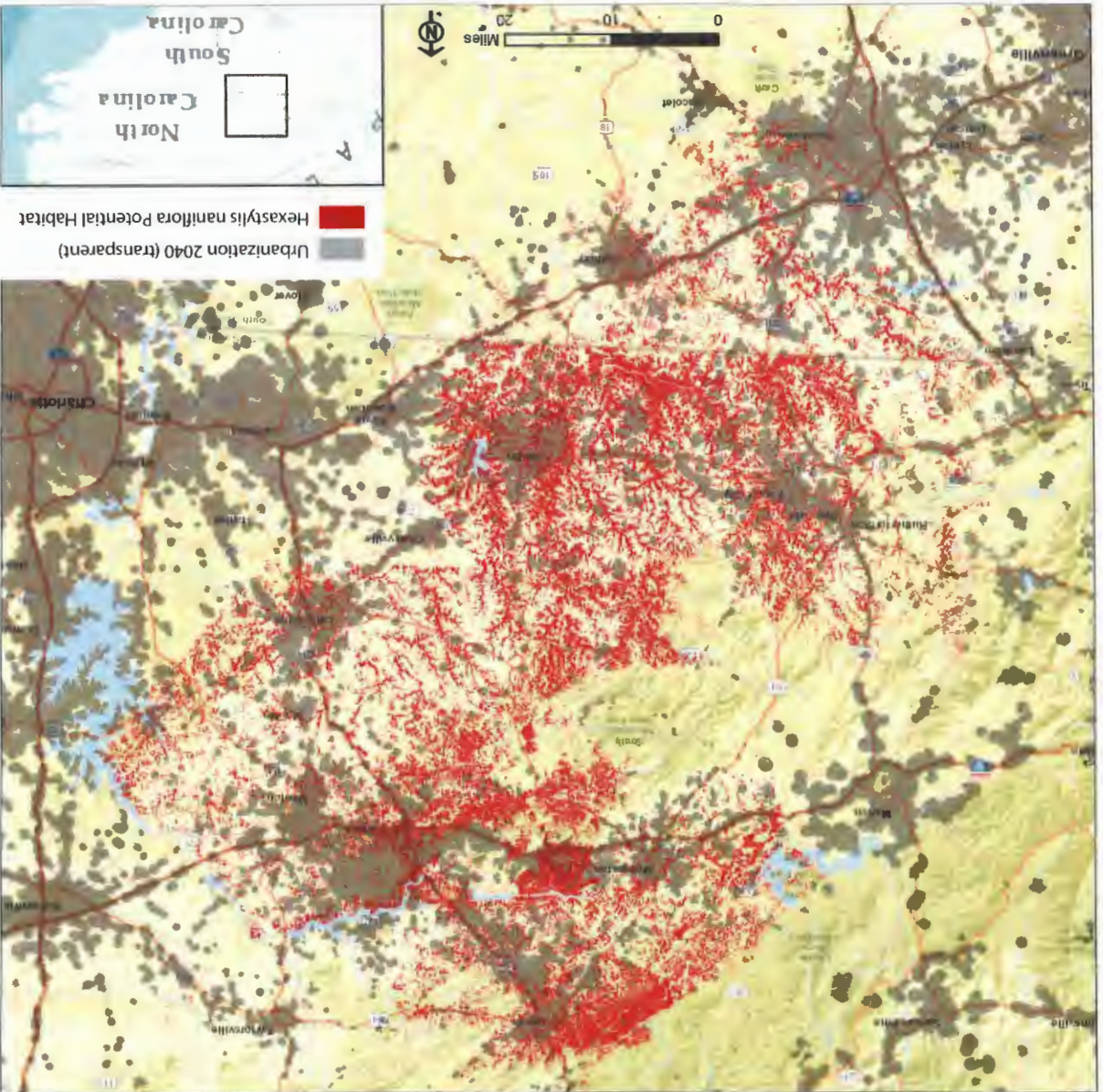
Our analysis of the past, current, and future influences on what the dwarf-flowered heartleaf needs for long term viability revealed that there are several influences that pose risks to future viability of the species. These risks are primarily related to habitat changes from development and long term climate change. We use projections of urban development to assess potential habitat loss and fragmentation. We also considered how climate change may exacerbate the impacts of development in a qualitative fashion using a narrative approach.

Because the actual impacts of urbanization are unknown, we use three scenarios, projected out to the year 2040, to capture the uncertainty related to the potential impacts to each population's resiliency: Status Quo, Targeted Conservation, and High Development. Results of future projections within each scenario are focused on current populations and potential habitat identified by the Maxent model as described below. Based on the life span of the species, expert input, development as the key risk factor brought forward, uncertainty about future conditions, and lack of knowledge about where additional populations may persist on the landscape, we chose to project populations out to the year 2040 under each scenario, but no further.

In constructing our scenarios, we considered two main influences by which species viability projections could be affected: location of additional populations (positive influence) and habitat loss and fragmentation due to urban development (negative influence). Habitat quantity can be negatively impacted by development or land use change (particularly on private lands) or positively impacted by land acquisition, restoration, and/or introductions into unoccupied sites that already have suitable habitat.

967 We use the Slope, Land cover, Exclusion, Urbanization, Transportation, and Hillshade
968 (SLEUTH) models to determine areas predicted to be urbanized by 2040 (Figure 6.1). SLEUTH
969 is a cellular automata model that applies transition rules to the states of a gridded series of cells,
970 and in this case the transition is that from undeveloped to developed land cover, otherwise
971 known as urbanization, and has been successfully applied worldwide over the last 15 years to
972 simulate land use change (Clarke 1995).
973
974 **Figure 6.1.** Results of the SLEUTH model with *Hexastylis naniflora* potential habitat predicted
975 by the MAXENT model overlaid.
976

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The SLEUTH model predictions are broken down by probabilities of urbanization, ranging from 0-100%. We chose 80% probability as our cutoff, as this cutoff has been used by USGS and other SSAs, and this threshold represents a highly likely outlook for urbanization of the landscape. To forecast viability using urban development projections, we assessed the following:

- % increase in projected development (SLEUTH probability of urbanization >80%) within current populations (from Current Conditions—68 populations)

I thought this was 78?

986 • % increase in projected development (SLEUTH probability of urbanization >80%) within
 987 areas delineated as potential habitat by the Maxent habitat model

988
 989 There is no data available on the exact relationships between urbanization and the impacts to
 990 dwarf-flowered heartleaf. We do know that several current populations are located in areas with
 991 surrounding urban landscapes. We also know that urban development has led to extirpation of
 992 populations in the past through loss of habitat. Because of this uncertainty, we attempted to
 993 capture unknowns in two ways. First, our scenarios reflect a range of potential impacts from
 994 urban development. Also, we used two thresholds for % increase in urban development to
 995 capture potential deleterious effects: 25% and 50%. Our assumptions were that very small
 996 increases in development are unlikely to negatively impact populations; development increase of
 997 at least 25% of the area of current populations was likely to have some negative impacts;
 998 development increase of at least 50% was likely to have significant impacts to populations. We
 999 also assume that populations currently on protected lands are likely to see smaller impacts from
 1000 urbanization compared to those that are not protected, but protection status (perpetuity vs non-
 1001 perpetuity) matters. For example, Registered Heritage Areas are non-binding agreements with
 1002 a land owner, and if the land changes ownership, or the owner decides not to continue with the
 1003 agreement, then the Registry is no longer valid. Appendix 4 shows the protection status of each
 1004 delineated population which helped to inform our assessment of resilience under each scenario.

1005
 1006 We also assessed potential positive effects by integrating the potential location or rediscovery of
 1007 additional populations throughout the range into two of our scenarios: Targeted Conservation
 1008 and Status Quo. We believe this is appropriate for several reasons. First, location of new EOs is
 1009 common; many of the populations we consider for Current Conditions include detections that
 1010 have occurred within the last few years. Second, we did not include many older detections (i.e.
 1011 only included detections since 2005), although many of those detections are likely to
 1012 persist. Dwarf-flowered heartleaf is a long-lived perennial, and several EOs have been revisited
 1013 after more than 10 years and the species was present. For example, one such EO was first
 1014 observed in 1957 and next observed in 2001. It seems as long as suitable habitat is still present it
 1015 is reasonable to assume that the species is still there. Finally, there is plenty of predicted suitable

1016 habitat present within older EOs based on the Maxent model predictions that were not included

why not?

1017 as current populations.

1018

1019 The first step in identifying additional areas where dwarf-flowered heartleaf is likely to be found

1020 in the future, was to identify EOs from populations that were last observed prior to 2005 (i.e. our

1021 cut-off for current populations). Although our focus is on older EOs, where dwarf-flowered

1022 heartleaf is likely to persist into the future, we also included current EOs (2005-current) in our

1023 analysis because we were interested in how the older EOs compared to those known to be

1024 persisting on the landscape since 2005. Also, by including older EOs that are within current

1025 delineated populations, we can investigate whether current populations might be predicted to

1026 contain more plants than the most recent abundance estimate. For example, many of our current

1027 populations consist of multiple EOs, and we only considered EOs that were detected from 2005-

1028 current. If these older EOs within current populations that were not included in our Current

1029 Condition assessment are found to be likely to persist, then it is possible we underestimated the

1030 resilience of that population.

1031

1032 Once these older EOs were identified, we created a 1,000 meter buffer around the population and

1033 calculated a number of useful metrics including resilience category based on the last known

1034 abundance estimate, Maxent habitat model metrics, and the results of the SLEUTH model to

1035 further refine a list of potential sites where the species would likely be found to persist within our

1036 20-25 year projection window. Resilience categories were assessed using last known abundance

1037 in the same way as populations assessed in the Current Conditions section (i.e. low = less than

1038 100 individuals; moderate = 100-500 individuals; high = 500-1000 individuals; very high =

1039 greater than 1,000 individuals). We assessed two habitat metrics for these older EOs: average

1040 Maxent score and % Maxent classified as 0.8-1.0 score. Average Maxent score was calculated

1041 by taking the mean Maxent score of all potential habitat within the 1,000 foot buffer. The %

1042 Maxent classified as 0.8-1.0 represents the percentage of all potential habitat within the 1,000

1043 foot buffer that falls within the highest habitat class. Together, these two habitat metrics give

1044 general estimates of habitat quantity and quality. Finally, we calculated the total percentage of

1045 the 1,000 foot buffer around each EO that is projected to be urbanized in the year 2040, which

1046 helps capture the primary risk factor of development when assessing the areas where dwarf-

and what
does the
maxent score
actually tell
me? that is
not explained

only the buffer? not the
EO itself?
I don't know what "highest" means here
most suitable? as

1047 flowered heartleaf is likely to persist. Table 6.1 (North Carolina) and 6.2 (South Carolina) show all of the EOs we considered and the corresponding metrics associated with resilience categories, urban development, and habitat scores.

1051 **Table 6.1.** North Carolina raw data for metrics assessed to investigate potential sites where dwarf-flowered heartleaf was historically found and is likely to persist. Resilience categories are based on last known abundance estimates as follows: 1 = low; 2 = moderate; 3 = high; 4 = very high. MAXENT Average Mean refers to the mean Maxent score of all potential habitat. % Maxent classified as 0.8-1.0 represents the percentage of all potential habitat that falls within the highest habitat class. % Urban Development refers to the percentage of the 1,000 foot buffer around the EO that is projected to be urbanized in the year 2040.

EO not part of a current population
EO included as part of a current population
EO is a part of a current population but last detection was prior to 2005
Eliminated/not scored

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
1	2	34	1	3
2				
3	2	22	0	10
4	2	22	0	7
5	2	21	0	0
6				
8	1	27	0	6
9	3	44	4	0
10	4	33	2	0
11				
12	4	54	10	0
13	1	31	1	30
14	2	61	16	7
15				
16	4	18	0	47
17	1	50	13	0
18	1	36	8	2
19				
20	2	22	1	88
21	2	34	4	54
23	4	15	0	8
25	1	47	15	30
27				

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
28	2	43	12	29
29	4	43	8	30
30	4	27	2	74
31	4	30	3	86
32	2	34	2	47
33	2	33	3	0
34	1	49	13	63
35	1	42	10	23
36	1	19	0	12
37	4	41	6	17
38	2	14	0	46
39	1	19	0	11
40	2	37	2	32
44	4	20	0	59
45	1	27	5	13
46	3	42	6	6
47	1	28	1	96
48	1	14	0	12
49	4	61	14	5
50				
51	4	52	11	18
52	2	46	4	0
53	1	35	4	24
54	1	35	1	10
55	4	30	0	0
56	2	40	2	6
57	2	21	0	80
58	1	42	5	0
59	2	11	0	49
60	1	25	0	2
61	3	41	0	0
62	2	34	0	0
63	1	27	0	6
64	2	39	9	11
69	2	46	11	19
70	2	38	1	0
71	2	30	2	0
72	2	52	14	0
73	4	60	17	1

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
74	3	65	14	4
75	4	47	6	9
76	4	42	4	10
77	3	31	1	27
79	2	39	1	0
80	1	43	4	15
83	2	17	0	11
84	2	13	0	1
85	2	42	4	5
87				
89	2	13	2	0
90	2	28	2	0
91	1	49	5	0
92	2	15	0	30
106	4	39	4	38
107	1	14	0	40
113	4	46	4	7
114				
115	2	37	3	26
118	3	42	0	9
121	2	41	5	0
122	1	12	0	39
124	1	12	0	9
125	4	15	0	41
130	2	17	0	24
149	4	64	17	3
151	2	16	0	27
154	4	30	1	22
157	2	20	0	0
158	3	36	7	5
159	4	62	24	60
160	3	62	24	32
161	4	64	28	30
162	1	32	2	58
163	2	15	0	56
164	3	18	0	52
165	1	13	0	56
166	1	14	0	40
167	4	30	0	20

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
168	4	19	0	34
169	1	30	0	12
170	2	17	0	40
172	1	39	3	7
173	2	30	1	48
174	1	42	4	16
175				
180	2	21	1	0
181	4	29	2	0
182	4	45	4	0
183	2	15	0	5
184	4	19	0	19
187	2	20	1	35
188	2	24	0	53
189	1	25	0	14
190				
191	2	34	2	0
192	2	35	3	0
193	2	36	7	6
194	4	51	14	18
195	1	21	0	96
196	1	23	4	67
197	4	35	8	38
198	2	32	6	25
199	2	29	5	43
200	1	26	2	87
201	1	39	4	63
202	4	35	4	85
203	1	43	4	49
204				
205	2	43	1	49
206	1	37	3	66
207	2	33	2	85
208	1	32	1	67
209	2	33	2	94
210				
212	1	37	3	85
213	1	36	4	72
219	1	32	1	4

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
222	2	23	3	7
223				
224	1	22	3	17
225	2	24	2	12
227	4	55	2	5
229	2	28	0	21
230	1	54	15	13
231	1	41	7	0
233	4	53	12	14
235	2	50	8	6
236	2	62	14	5
237	2	67	16	5
238	4	51	15	0
239	2	63	14	5
240	1	57	18	0
241	2	62	16	3
242	1	53	9	0
246	1	62	13	4
249	4	47	5	0
250	4	45	4	0
251	4	43	4	0
254	2	54	18	6
255				
256	2	54	15	13
258	3	19	0	51
259	4	25	0	0
262	4	29	2	50
263				
264				
265				
266				
267	2	29	1	0
268	1	33	2	0
269	2	49	17	0
270	1	46	18	1
271	1	26	7	0
272	1	33	0	71
273	2	28	2	0
274	2	50	8	0

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
275	2	12	0	0
276	4	42	5	21
277				
278				
279	1	32	4	89
280	2	64	30	30
281	1	64	31	36
282	1	64	31	51
283	1	65	34	59
284	1	64	35	45
286				
287	2	15	0	35
291	2	21	1	84
292	2	14	0	83
293	1	8	0	16
294	2	36	4	61
296	2	3	0	5
297				
298	2	16	0	1
299	1	12	0	0
300	1	9	0	18
303	2	31	0	0
304	2	31	0	0
305	1	30	2	0
306	1	4	0	53
308	2	15	0	3
309	1	5	0	0
310	4	58	26	35
311	2	15	0	0
312	4	17	0	57
313				
314				
315	1	36	4	61
317	1	15	0	53
318	2	34	4	52
319	4	43	4	10
320	4	41	6	98
321				

EO Code	Min		Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
	1	4				
	3	67			35	98
	0				0	0

Table 6.2. South Carolina raw data for metrics assessed to investigate potential sites where dwarf-flowered heartleaf was historically found and is likely to persist. Resilience categories are based on last known abundance estimates as follows: 1 = low; 2 = moderate; 3 = high; 4 = very high. MAXENT Average Mean refers to the mean Maxent score of all potential habitat. % Maxent classified as 0.8-1.0 represents the percentage of all potential habitat that falls within the highest habitat class. % Urban Development refers to the percentage of the 1,000 foot buffer around the EO that is projected to be urbanized in the year 2040.

EO not part of a current population
EO included as part of a current population
EO is a part of a current population but last detection was prior to 2005
Eliminated/not scored

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
1	2	21	0	0
2	2	1	0	4
3				
4	1	13	0	10
5	2	0	0	64
6	1	0	0	36
7	4	27	0	35
8	2	0	0	14
9				
10				
11	4	14	0	52
12				
13	1	7	0	100
14	4	14	0	43
15	1	0	0	4
16	4	22	0	38
17	4	22	0	33
18	3	19	0	52
19	1	12	0	65
20	2	5	0	100
21	3	5	0	90
22	1	0	0	0
23				

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
24	1	4	0	3
25	1	14	0	48
26	4	12	0	65
27	4	18	1	40
28	4	19	1	49
29				
30	2	7	0	88
31	4	0	0	0
32	2	7	0	93
33	2	2	0	20
34	1	31	3	1
35	1	23	1	53
36	2	6	0	0
37	1	24	2	0
38	4	5	0	37
39	1	6	0	1
40	2	6	0	20
41	1	11	0	87
42	2	3	0	6
43	1	23	0	43
44				
45				
46	1	10	0	96
47				
48				
49	3	8	0	70
50	2	5	0	54
51	1	0	0	35
52	3	0	0	0
53	2	10	0	66
54	2	9	0	91
55	1	4	0	99
56	2	14	0	96
57	3	15	0	38
59	2	4	0	17
60	4	17	1	12

Min	1	0	0	0
Max	4	31	3	100

EO_Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
---------	---------------------	----------------------	--------------------------------	---------------------

1069 Next, we implemented a set of ranking rules using the data from Tables 6.1 and 6.2 to further
 1070 assess which EOs had a higher likelihood of persistence on the landscape. We used SMART
 1071 methodology to quantify and implement our ranking rules. Because the metrics of interest vary
 1072 in data type (i.e. categorical vs continuous) and range of values (i.e. not all continuous variables
 1073 have the same maximum and minimum), our first step was to normalize all of the data on a scale
 1074 of 0-100. Normalization techniques allow for aggregation of criteria with numerical and
 1075 comparable data. We decided to analyze North and South Carolina data separately because the
 1076 Maxent model predicts habitat differently across state lines due to differences in soil
 1077 classification. We weighted each variable according to our opinion of the level of contribution
 1078 each variable had to the probability of persistence of that particular EO. This resulted in
 1079 abundance having the highest weight (100%), with habitat (as calculated by average Maxent
 1080 score) and urbanization given relatively similar weighting (80%). The results of the
 1081 normalization procedure and weighting can be found in Tables 6.3 and 6.4.

1083 **Table 6.3.** Normalized scores for SMART analysis of North Carolina EOs and weighting scores.
 1084 Resilience category represents the normalized scoring based on the last known abundance
 1085 (0=low; 33=moderate; 67=high; 100=very high); MAXENT Mean is the normalized score of the
 1086 average Maxent rank of all potential habitat; MAXENT percent 0.8-1 represents the normalized
 1087 score of the percentage of potential habitat that falls within the highest rank category; 80% or
 1088 greater SLEUTH Percent of Total is the total amount of current urbanization plus predicted
 1089 urbanization at year 2040 (>80% probability) from the SLEUTH model.

EO not part of a current population	EO included as part of a current population	EO is a part of a current population but last detection was prior to 2005	Eliminated/not scored
-------------------------------------	---	---	-----------------------

EO_Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
1	33	49	3	97
2				
3	33	30	0	90
4	33	29	0	93
5	33	28	1	100
6				

So this isn't projected rather
 is there a current? *cod. line?*
 different than the 1-4 previous
 categories from
 tables 6.1 + 6.2?



Can this be defined here?

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
8	0	37	0	94
9	67	65	11	100
10	100	46	6	100
11				
12	100	80	28	100
13	0	43	2	69
14	33	90	44	93
15				
16	100	23	0	52
17	0	73	37	100
18	0	52	22	98
19				
20	33	30	3	11
21	33	48	12	45
23	100	19	0	92
25	0	68	42	69
27				
28	33	62	33	71
29	100	63	22	69
30	100	38	5	24
31	100	43	8	12
32	33	48	5	52
33	33	47	8	100
34	0	73	37	35
35	0	60	29	77
36	0	25	0	88
37	100	60	17	82
38	33	17	0	53
39	0	24	0	89
40	33	54	7	67
44	100	26	1	40
45	0	37	14	86
46	67	60	18	94
47	0	39	2	2
48	0	17	0	88
49	100	91	39	95
50				
51	100	77	31	82
52	33	68	11	100

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
53	0	50	11	76
54	0	49	1	90
55	100	43	0	100
56	33	58	7	94
57	33	28	0	19
58	0	60	15	100
59	33	12	0	50
60	0	34	1	98
61	67	59	1	100
62	33	49	0	100
63	0	38	0	94
64	33	56	24	88
69	33	67	31	80
70	33	55	3	100
71	33	42	5	100
72	33	77	41	100
73	100	89	48	99
74	67	97	41	95
75	100	69	16	91
76	100	61	11	89
77	67	43	2	72
79	33	56	4	100
80	0	62	11	85
83	33	22	0	89
84	33	15	0	99
85	33	61	10	95
87				
89	33	15	5	100
90	33	38	5	100
91	0	71	13	100
92	33	18	0	70
106	100	56	10	61
107	0	16	0	59
113	100	68	11	93
114				
115	33	53	8	74
118	67	61	1	91
121	33	59	13	100
122	0	14	0	60

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
124	0	13	0	91
125	100	19	0	58
130	33	22	0	76
149	100	95	49	97
151	33	20	0	72
154	100	41	2	78
157	33	26	0	100
158	67	51	20	95
159	100	92	69	39
160	67	92	69	68
161	100	95	79	69
162	0	45	7	41
163	33	18	0	43
164	67	24	0	47
165	0	16	0	43
166	0	16	0	59
167	100	41	0	79
168	100	25	0	65
169	0	42	0	88
170	33	22	0	60
172	0	56	8	93
173	33	42	3	52
174	0	62	12	84
175				
180	33	28	2	100
181	100	41	6	100
182	100	66	12	100
183	33	18	1	95
184	100	24	0	81
187	33	27	2	64
188	33	33	0	46
189	0	33	1	86
190				
191	33	48	7	100
192	33	49	10	100
193	33	51	19	94
194	100	75	40	81
195	0	28	0	3
196	0	30	10	32

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
197	100	50	24	61
198	33	45	18	74
199	33	41	14	56
200	0	35	6	11
201	0	56	11	36
202	100	49	11	13
203	0	62	11	50
204				
205	33	62	4	50
206	0	52	8	33
207	33	47	4	14
208	0	45	4	32
209	33	46	5	4
210				
212	0	53	9	14
213	0	52	11	27
219	0	45	2	96
222	33	31	9	92
223				
224	0	29	8	83
225	33	32	6	88
227	100	81	7	95
229	33	39	0	79
230	0	80	44	87
231	0	59	20	100
233	100	79	34	86
235	33	74	22	94
236	33	93	41	95
237	33	100	46	95
238	100	74	41	100
239	33	94	40	94
240	0	85	51	100
241	33	93	47	97
242	0	78	27	100
246	0	93	38	95
249	100	68	13	100
250	100	65	12	100
251	100	62	11	100
254	33	80	51	93

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
255				
256	33	80	44	87
258	67	25	0	48
259	100	34	0	100
262	100	41	6	49
263				
264				
265				
266				
267	33	41	3	100
268	0	46	7	100
269	33	72	49	100
270	0	67	52	99
271	0	35	19	100
272	0	47	0	28
273	33	39	7	100
274	33	73	23	100
275	33	14	0	100
276	100	61	14	79
277				
278				
279	0	46	11	9
280	33	95	85	70
281	0	95	88	64
282	0	96	88	48
283	0	97	95	40
284	0	95	100	54
286				
287	33	18	0	64
291	33	28	4	14
292	33	16	0	16
293	0	7	0	84
294	33	52	11	38
296	33	0	0	95
297				
298	33	20	0	99
299	0	13	0	100
300	0	9	0	82
303	33	44	1	100

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
304	33	43	0	100
305	0	42	5	100
306	0	1	0	46
308	33	18	0	97
309	0	3	0	100
310	100	86	75	64
311	33	19	0	100
312	100	22	0	42
313				
314				
315	0	51	10	38
317	0	19	0	46
318	33	48	12	47
319	100	63	12	89
320	100	60	17	0
321				

Weights			
100	60	20	80

Table 6.4. Normalized scores for SMART analysis of South Carolina EOs and weighting scores. Resilience category represents the normalized scoring based on the last known abundance (0=low; 33=moderate; 67=high; 100=very high); MAXENT Mean is the normalized score of the average Maxent rank of all potential habitat; MAXENT percent 0.8-1 represents the normalized score of the percentage of potential habitat that falls within the highest rank category; 80% or greater SLEUTH Percent of Total is the total amount of current urbanization plus predicted urbanization at year 2040 (>80% probability) from the SLEUTH model.

EO not part of a current population
EO included as part of a current population
EO is a part of a current population but last detection was prior to 2005
Eliminated/not scored

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
1	33	67	14	100
2	33	2	0	96
3				
4	0	42	3	90
5	33	0	0	36

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
6	0	0	0	64
7	100	87	2	65
8	33	0	0	86
9				
10				
11	100	43	0	48
12				
13	0	23	0	0
14	100	43	0	57
15	0	0	0	96
16	100	72	1	62
17	100	70	1	67
18	67	62	0	48
19	0	37	0	35
20	33	16	0	0
21	67	15	0	10
22	0	1	0	100
23				
24	0	13	0	97
25	0	44	0	52
26	100	40	0	35
27	100	56	18	60
28	100	60	28	51
29				
30	33	22	0	12
31	100	0	0	100
32	33	23	0	7
33	33	5	0	80
34	0	100	100	99
35	0	75	34	47
36	33	18	0	100
37	0	78	66	100
38	100	16	0	63
39	0	19	0	99
40	33	18	0	80
41	0	36	0	13
42	33	10	0	94
43	0	72	0	57
44				

EO_Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
45				
46	0	32	0	4
47				
48				
49	67	27	0	30
50	33	16	0	46
51	0	1	0	65
52	67	0	0	100
53	33	33	0	34
54	33	29	0	9
55	0	13	0	1
56	33	43	0	4
57	67	47	8	62
59	33	13	0	83
60	100	53	21	88

Weights			
100	60	20	80

1102

1103 To determine a final rank for likelihood of persistence, we calculated a weighted sum for each
 1104 EO. We then converted the weighted sum to a final rank value that ranged from 0-100. Finally,
 1105 we determined the top 10% or 90th percentile, and top 25% or 75th percentile ranking for EOs in
 1106 each state. Table 6.5 summarizes the final ranks and top 10% and 25% percentile ranks for
 1107 North and South Carolina. We will include the top 10% in the status quo scenario, and the top
 1108 25% in the conservation scenario.

1109

1110 **Table 6.5.** Final Rank Scores for EOs in North and South Carolina. Dark green represents the
 1111 top 10% of scores, and light green includes the top 25% of scores.

EO not part of a current population

EO included as part of a current population

EO is a part of a current population but last detection was prior to 2005

Eliminated/not scored

1112

South Carolina

EO_Code	Final Score
60	79
7	79
17	75

North Carolina

EO_Code	Final Score
149	94
73	93
49	92

I don't know what this table is supposed to be telling me.

You lost me with too much stats. Less detail, more explanation of purpose for normalizing and using percentiles

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16	74
27	71
28	70
31	69
14	66
11	63
38	62
34	61
1	60
26	59
52	56
57	56
18	55
37	54
36	48
42	44
2	43
40	42
59	41
49	41
8	39
33	39
4	37
39	35
35	34
43	34
24	33
21	32
22	31
53	31
50	31
15	30
25	26
56	24
5	24
54	22
30	22
32	20
51	20
6	20
19	19

12	236
90	238
88	161
87	227
96	249
86	233
85	182
85	250
84	251
84	194
84	51
84	310
84	75
84	113
81	319
81	76
81	74
80	10
79	181
79	55
79	37
78	276
77	259
77	159
76	29
73	160
72	167
72	9
72	154
71	23
71	106
71	197
70	61
70	46
69	184
69	237
68	158
68	118
68	241
67	239
66	236

28	51
242	51
17	51
5	50
180	50
270	50
157	50
222	49
230	49
115	48
281	48
91	48
4	48
298	48
311	48
225	48
198	47
89	47
3	47
84	47
308	47
275	47
183	46
40	46
284	46
258	46
231	46
229	46
58	46
164	46
83	45
282	44
18	44
205	43
172	42
296	42
283	42
268	42
80	41
130	41
174	41

265	0
266	0
277	0
278	0
286	0
297	0
313	0
314	0
321	0

Below we describe how we integrated potential positive and negative influences across the scenarios. We can assume there is some tipping point at which an area becomes so urbanized it is unsuitable for dwarf-flowered heartleaf, but we don't know exactly what that tipping point is. Similarly, we can assume additional populations are likely to be found or rediscovered across the range, but there is no clear way to predict the exact number or location of these populations. Although there is great uncertainty associated with how the species will be influenced by these factors, the three scenarios are intended to capture the range of this uncertainty. Note, changes in climate have potential to exacerbate the effects of urbanization, but these effects are not likely to occur within our projection window (e.g. 2040).

Status Quo Scenario

Under the status quo scenario, we assume a few populations will be identified as persisting throughout the range, and that there will be a range of impacts from urbanization that are related to the % increase in urban development and whether a population is protected or not. We assessed population resilience under the following assumptions:

- Two additional populations are identified as persisting based on Maxent model metrics, last known abundance category, and total predicted urbanization from SLEUTH modelling. Six additional EOs within currently delineated populations not included in our Current Conditions analysis are predicted to persist based on the same metrics.
- Potential impacts of urban development based on SLEUTH Model projections focused on current delineated populations:
 - Protected areas

Just because we have in the past, doesn't mean we will continue to find more. That's a big assumption and makes a big difference. For the sure about this?

in addition to what #?

1137
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High Development Scenario

Under the high development scenario, we assume no additional populations will be identified as persisting throughout the range, and that impacts from urbanization that are relatively high, and are also affected by whether a population is protected or not. We assessed population resilience under the following assumptions:

- No additional populations are identified as persisting
- Potential impacts of urban development based on SLEUTH Model projections focused on current delineated populations:

- Protected areas

- Protected in perpetuity—population drops 1 resilience rank if % increase in urbanization exceeds >50% threshold
- Voluntary protection/non-perpetuity—population drops 1 resilience rank if % increase in urbanization exceeds >25% threshold; population drops 2

resilience ranks if % increase in urbanization exceeds >50% threshold

- Non-protected—population drops 1 resilience rank if % increase in urbanization exceeds >25% threshold; population drops 2 resilience ranks if % increase in

urbanization exceeds >50% threshold; extirpation of populations if % increase in urbanization exceeds >90% threshold.

Targeted Conservation Scenario

Under the targeted conservation scenario, we assume it is likely several additional populations (i.e. more than status quo scenario) will be identified as persisting throughout the range. The

- Protected in perpetuity—no negative impacts from urbanization
- Voluntary protection/non-perpetuity—population drops 1 resilience rank if % increase in urbanization exceeds >50% threshold
- Non-protected—population drops 1 resilience rank if % increase in urbanization exceeds >25% threshold; population drops 2 resilience ranks if % increase in urbanization

Why just 1 resilience rank?

urbanization exceeds >50% threshold

Why this high? Do we really believe anything would persist at higher than 80-75% development?

1166 range of impacts from urbanization are the same as the Status Quo scenario. We assessed

1167 population resilience under the following assumptions:

- 1168 • Six populations are identified as persisting based on Maxent model metrics, last known

1169 abundance category, and total predicted urbanization from SLEUTH modelling. Six

1170 additional EOs within currently delineated populations not included in our Current

1171 Conditions analysis are predicted to persist based on the same metrics.

- 1172 • Potential impacts of urban development based on SLEUTH Model projections focused on

1173 current delineated populations:

- 1174 ○ Protected areas

- 1175 ▪ Protected in perpetuity—no impacts from urbanization

- 1176 ▪ Voluntary protection/non-perpetuity—population drops 1 resilience rank if

1177 % increase in urbanization exceeds >50% threshold

- 1178 ○ Non-protected—population drops 1 resilience rank if % increase in urbanization

1179 exceeds >25% threshold; population drops 2 resilience ranks if % increase in

1180 urbanization exceeds >50% threshold

1182 Future Resilience

1184 Our focus on future resilience of dwarf-flowered heartleaf is on the potential impacts from

1185 urbanization. Table 6.6 shows a summary of currently delineated populations and the predicted

1186 urban development to occur within each of the populations. The table only includes those

1187 populations that already have some current amount of urban development, or are predicted to

1188 have some amount of development occur by the year 2040. Populations not included in this

1189 table are not predicted to be urbanized at all, so for the purposes of future analysis, will be

1190 assumed to retain the same resilience category as current. For those populations included in the

1191 table, we focus on those populations that are anticipated to increase in urbanization beyond a

1192 threshold value, depending on the scenario, but thresholds include >25% and >50% increases:

1193 Also taken into account is whether or not a population is on protected lands, and if so, whether

1194 the population is protected in perpetuity or not. Below is a summary of projected future

1195 resilience under each of the three scenarios.

what
about 95%
identified
as the last
page?

1231 very high (27); high (6); moderate (23); low (17); and 2 additional populations identified as
 1232 persisting, with an unknown resilience. Six EOs within currently delineated populations not
 1233 included in our Current Conditions analysis are predicted to persist, but resilience is unchanged
 1234 because each of the populations are already predicted to be of very high resilience. When
 1235 comparing future population resilience to current condition a few populations drop in their
 1236 resilience category. One current population of very high resilience is predicted to drop to high
 1237 resilience; two moderate populations are predicted to drop to low resilience; and five populations
 1238 (one currently moderate and four currently low) are predicted to be extirpated due to urban
 1239 development. Of the seven additional populations predicted to persist under this scenario, four
 1240 are in South Carolina, and three in North Carolina. We did not assess resilience for these
 1241 additional populations, but it is worth mentioning that the last time these populations were
 1242 detected, resilience was very high (2), high (1), and moderate (4).

Table 6.7. Predicted resilience categories for *Hexastylis naniflora* populations under the Status Quo scenario, and comparison to current condition.

Site Name	Current Resilience	Status Quo
DNR Peters Creek Heritage Preserve	very high	very high
Cowpens NBF	very high	very high
Mill Creek Forest and Seep	very high	very high
Island Creek Heath Bluff	very high	very high
NCDOT TIP: R-2824	very high	very high
Murrays Mill/Uppper Balls Creek NA	very high	very high
Big Horse Creek Rare Plant Site	very high	very high
Broad River/Sandy Run NA	very high	very high
New Hope Springhead Swamp	very high	very high
Facebook Site	very high	very high
Davenport Road/Mountain View Rare Plant Site	very high	very high
Broad River: Floyds Creek	very high	very high
Catawba River: Hoyle Ck-Micol Ck	very high	very high
South Fork Catawba R: Clark Ck, Miller Br, Cata Mem Hos	very high	very high
Buffalo Creek: Tributaries N and S of SR 2047	very high	high
Buffalo Creek: Kings Mountain Res	very high	very high
Broad River: Brushy Creek	very high	very high
Peaked Top Rare Plant Site/Foothills Landfill	very high	very high
Jacob Fork West Corridor	very high	very high
Floyds Creek Tributary Rare Plant Site	very high	very high

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Site Name	Current Resilience	Status Quo
New Bethel Rare Plant Site	very high	very high
Leepers Creek Heartleaf Site	very high	very high
Cliffside Steam Station	very high	very high
Rhyme Conservation Preserve	very high	very high
Glade Creek, Alex County	very high	very high
Richardson Creek trib above Toms Lake	very high	very high
Gunpowder Creek: South of Hudson	very high	very high
Taylor Blaylock Res	very high	very high
Little Gunpowder Creek Rare Plant Site 1	high	high
Little Gunpowder Creek Rare Plant Site 2	high	high
Buffalo Creek Rare Plant Site	high	high
Northern Catawba County	high	high
Rock Barn Solar Farm	high	high
NCDOT TIP R-2824	moderate	moderate
Third Creek Rare Plant Site	moderate	moderate
Knob Creek NA	moderate	moderate
Buffalo Creek: Northeast of SR 1903	moderate	moderate
West Shelby Mesic Slope	moderate	low
Cat Square Heartleaf Forest	moderate	low
Kross Keys NA	moderate	moderate
First Broad River: Crooked Run Creek	moderate	moderate
NCDOT non-TIP Div 12 road const at SR 1115	moderate	moderate
South Fork Catawba River Jacobs Fork and Camp Creek	moderate	moderate
Catawba River: North Fork Mountain Creek	moderate	moderate
Catawba River: Lake James	moderate	moderate
Hogpen Branch Transplant Site	moderate	moderate
Jonas Road Rare Plant Site	moderate	extirpated
South Fork Catawba River, Henry Fork	moderate	moderate
No Business Creek, Boyd Tract	moderate	moderate
Broad River/Sandy Run NA	moderate	moderate
Buffalo Shoals Creek	moderate	moderate
Fox Knoll Farm	moderate	moderate
Forest City: Adj to Isothermal CC	moderate	moderate
Hickory Area	moderate	moderate
UT of Kings Mountain Res	moderate	moderate
Brushy Creek Headwaters	moderate	moderate
Smith Cliff/Henry Fork River	moderate	moderate
Simms Hill/Little River Uplands	moderate	moderate
Collinsville (Hughes) Creek Slopes	moderate	moderate

Site Name	Current Resilience	Status Quo
Burke County - Drowning Creek UT	moderate	moderate
Sandy Spring Church Springhead Swamp	low	low
First Broad River: Hickory Creek	low	low
Buffalo Creek: Ravine	low	extirpated
Buffalo Creek: Potts Creek	low	extirpated
Smith Cliff/Henry Fork River	low	low
Pott Creek	low	low
Northeast Lincoln: UT Walker Branch	low	extirpated
Gunpowder Creek	low	low
Killian Crossroads	low	low
Beaverdam Crk at First Broad River	low	low
Lincoln County, SR-1314	low	low
Levan Family Farm	low	low
Fanjoy Road Site	low	extirpated
First Broad River: Beaverdam Creek Tribs	low	low
South Mountains Pleasant Grove Uplands	low	low
NCDOT TIP R-3603A	low	low
Hickory Creek - UT (Shelby High School)	low	low
Boulder Creek Subdivision	low	low
Gateway Elementary School	low	low
First Broad River (North Carolina)	n/a	present
Cherokee Creek/Bonner and Robin School Roads	n/a	present

High Development Scenario

In the High Development scenario, there are predicted to be 72 populations of dwarf-flowered heartleaf on the landscape (Table 6.8). The predicted resilience of the extant populations are as follows: very high (27); high (4); moderate (25); and low (16). No new future populations are predicted to be discovered. When comparing future population resilience to current condition a few populations drop in their resilience category. One current population of very high resilience is predicted to drop to moderate resilience; one high resilience population is predicted to drop to moderate; two moderate populations are predicted to drop to low resilience; and six populations (one currently moderate and five currently low) are predicted to be extirpated due to urban development.

Table 6.8. Predicted resilience categories for *Hexastylis naniflora* populations under the High Development scenario, and comparison to current condition.

Site Name	Current Resilience	High Development
DNR Peters Creek Heritage Preserve	very high	very high
Cowpens NBF	very high	very high
Mill Creek Forest and Seep	very high	very high
Island Creek Heath Bluff	very high	very high
NCDOT TIP: R-2824	very high	very high
Murrays Mill/Upper Balls Creek NA	very high	very high
Big Horse Creek Rare Plant Site	very high	very high
Broad River/Sandy Run NA	very high	very high
New Hope Springhead Swamp	very high	very high
Facebook Site	very high	very high
Davenport Road/Mountain View Rare Plant Site	very high	very high
Broad River: Floyds Creek	very high	very high
Catawba River: Hoyle Crk-Micol Crk	very high	very high
South Fork Catawba R: Clark Crk, Miller Br, Cata Mem Hos	very high	very high
Buffalo Creek: Tributaries N and S of SR 2047	very high	moderate
Buffalo Creek: Kings Mountain Res	very high	very high
Broad River: Brushy Creek	very high	very high
Peaked Top Rare Plant Site/Foothills Landfill	very high	very high
Jacob Fork West Corridor	very high	very high
Floyds Creek Tributary Rare Plant Site	very high	very high
New Bethel Rare Plant Site	very high	very high
Leepers Creek Heartleaf Site	very high	very high
Cliffside Steam Station	very high	very high
Rhyme Conservation Preserve	very high	very high
Glade Creek, Alex County	very high	very high
Richardson Creek trib above Toms Lake	very high	very high
Gunpowder Creek: South of Hudson	very high	very high
Taylor Blaylock Res	very high	very high
Little Gunpowder Creek Rare Plant Site 1	high	high
Little Gunpowder Creek Rare Plant Site 2	high	high
Buffalo Creek Rare Plant Site	high	high
Northern Catawba County	high	moderate
Rock Barn Solar Farm	high	high
NCDOT TIP R-2824	moderate	moderate
Third Creek Rare Plant Site	moderate	moderate
Knob Creek NA	moderate	moderate
Buffalo Creek: Northeast of SR 1903	moderate	moderate
West Shelby Mesic Slope	moderate	low
Cat Square Heartleaf Forest	moderate	low

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1214	Table 6.6. Results of the SLEUTH model. Populations consist of both stand-alone EOs and
1215	aggregates of multiple EOs following the definition of delineating demographic populations
1216	from Chapter 4. Included are only those populations that already have some current amount of
1217	urban development, or are predicted to have some amount of development occur by the year
1218	2040. Red cells indicate populations that are predicted to increase >50% in urbanization.
1219	Orange cells indicate populations that are predicted to increase >25% in urbanization.
1220	

Population Number	Total Area (sq m)	Already classed Urban	80% chance	90% chance	95% chance	97.5% chance	100% chance	>80%
206	17346.37096	0.40%	0.00%	0.00%	0.00%	6.24%	93.41%	99.63%
306	7804.656249	0.00%	0.00%	0.00%	0.00%	0.00%	22.40%	95.24%
208	55360.86786	17.31%	0.00%	0.00%	0.00%	0.00%	82.69%	82.69%
279	19551.661571	0.00%	0.00%	0.00%	0.00%	0.00%	80.85%	80.85%
214	15043.2984	0.00%	0.00%	1.44%	10.97%	0.00%	55.72%	68.13%
248	25486.15611	28.80%	0.00%	3.22%	0.02%	0.02%	53.03%	56.30%
316	43177.79587	20.06%	0.00%	16.68%	7.08%	0.00%	20.67%	44.43%
247	49898.17159	5.87%	0.00%	6.37%	0.00%	0.00%	23.35%	29.73%
291	11666.76374	35.39%	12.28%	13.53%	2.43%	0.00%	0.23%	28.47%
287	7901.775408	0.00%	0.00%	11.50%	0.00%	0.00%	14.25%	25.75%
312	6535.273235	0.00%	25.28%	0.00%	0.00%	0.00%	0.00%	25.28%
32	31220.60253	60.74%	0.00%	20.39%	0.00%	0.00%	0.00%	20.39%
177	26954.54153	25.34%	12.19%	0.92%	0.10%	5.31%	0.13%	18.66%
292	15611.18205	0.00%	0.00%	0.00%	0.00%	0.00%	18.40%	18.40%
261	21644.22924	0.00%	0.00%	13.21%	3.35%	0.00%	0.00%	16.56%
295	23486.00987	18.20%	0.00%	3.41%	11.99%	0.25%	0.00%	15.65%
125	20742.3249	0.00%	1.02%	5.65%	6.67%	0.00%	0.00%	13.34%
59	8172.007769	0.00%	13.09%	0.00%	0.00%	0.00%	0.00%	13.09%
302	120342.0641	1.46%	2.55%	2.55%	0.77%	2.33%	3.98%	12.19%
178	376781.2214	28.59%	2.79%	2.40%	0.68%	0.59%	2.64%	9.11%
93	43754.11642	0.19%	0.00%	0.00%	0.00%	0.00%	7.82%	7.82%
77	6044.427562	0.00%	1.51%	6.14%	0.00%	0.00%	0.00%	7.64%
179	15145.19453	85.06%	1.14%	0.00%	5.12%	0.00%	0.49%	6.75%
44	15081.76951	61.17%	0.27%	0.00%	0.00%	0.00%	4.68%	4.95%
252	39595.93143	63.47%	0.00%	3.80%	0.00%	0.00%	0.00%	3.80%
100	423621.7376	9.01%	1.32%	1.10%	0.72%	0.14%	0.00%	3.27%
276	123688.7819	0.61%	0.36%	1.87%	0.01%	0.00%	0.00%	2.24%
216	66424.06073	0.00%	0.91%	0.00%	0.00%	0.00%	0.00%	0.91%
154	33924.92259	0.00%	0.00%	0.37%	0.00%	0.00%	0.00%	0.37%
29	249998.8742	0.00%	0.00%	0.05%	0.00%	0.00%	0.00%	0.05%
29	30711.68144	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	36339.91976	11.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	24498.03483	24.77%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
31	42929.76479	100.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
96	95947.32128	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
130	1168.240433	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
176	39787.48373	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
195	7805.599588	99.94%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
317	584.7346337	99.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
318	5396.859208	99.74%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
320	125.5182447	98.79%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Status Quo Scenario

1221 1222 1223 1224 1225 1226 1227 1228 1229 1230
 In the Status Quo scenario, there are predicted to be 75 populations of dwarf-flowered heartleaf on the landscape (Table 6.7). The predicted resilience of the extant populations are as follows:

Site Name	Current Resilience	High Development
Kross Keys NA	moderate	moderate
First Broad River: Crooked Run Creek	moderate	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork	moderate	moderate
Catawba River Jacobs Fork and Camp Creek	moderate	moderate
Catawba River: North Fork Mountain Creek	moderate	moderate
Catawba River: Lake James	moderate	moderate
Hogpen Branch Transplant Site	moderate	moderate
Jonas Road Rare Plant Site	moderate	extirpated
South Fork Catawba River, Henry Fork	moderate	moderate
No Business Creek, Boyd Tract	moderate	moderate
Broad River/Sandy Run NA	moderate	moderate
Buffalo Shoals Creek	moderate	moderate
Fox Knoll Farm	moderate	moderate
Forest City: Adj to Isothermal CC	moderate	moderate
Hickory Area	moderate	moderate
UT of Kings Mountain Res	moderate	moderate
Brushy Creek Headwaters	moderate	moderate
Smith Cliff/Henry Fork River	moderate	moderate
Sims Hill/Little River Uplands	moderate	moderate
Collinsville (Hughes) Creek Slopes	moderate	moderate
Burke County - Drowning Creek UT	moderate	moderate
Sandy Spring Church Springhead Swamp	low	low
First Broad River: Hickory Creek	low	low
Buffalo Creek: Ravine	low	extirpated
Buffalo Creek: Potts Creek	low	extirpated
Smith Cliff/Henry Fork River	low	low
Pott Creek	low	low
Northeast Lincolnton: UT Walker Branch	low	extirpated
Gunpowder Creek	low	extirpated
Killian Crossroads	low	low
Beaverdam Crk at First Broad River	low	low
Lincoln County, SR-1314	low	low
Levan Family Farm	low	low
Fanjoy Road Site	low	extirpated
First Broad River: Beaverdam Creek Tribs	low	low
South Mountains Pleasant Grove Uplands	low	low
NCDOT TIP R-3603A	low	low
Hickory Creek - UT (Shelby High School)	low	low
Boulder Creek Subdivision	low	low

Site Name	Current Resilience	High Development
Gateway Elementary School	low	low

Targeted Conservation Scenario

1261
1262
1263
1264 In the Targeted Conservation scenario, there are predicted to be 79 populations of dwarf-flowered heartleaf on the landscape (Table 6.9). The predicted resilience of the extant populations are as follows: very high (27); high (6); moderate (23); low (17); and 6 additional populations discovered to persist, with an unknown resilience. Six EOs within currently delineated populations not included in our Current Conditions analysis are predicted to persist, but resilience is unchanged because each of the populations are already predicted to be of very high resilience. When comparing future population resilience to current condition a few populations drop in their resilience category. One current population of very high resilience is predicted to drop to high resilience; two moderate populations are predicted to drop to low resilience; and five populations (one currently moderate and four currently low) are predicted to be extirpated due to urban development. Of the sixteen additional populations predicted to persist under this scenario, ten are in South Carolina, and six in North Carolina. We did not assess resilience for these additional populations, but it is worth mentioning that the last time these populations were detected, resilience was very high (2), high (1), moderate (11), and low (2).

Table 6.9. Predicted resilience categories for *Hexastylis naniflora* populations under the Targeted Conservation scenario, and comparison to current condition.

Site Name	Current Resilience	Targeted Conservation
DNR Peters Creek Heritage Preserve	very high	very high
Cowpens NBF	very high	very high
Mill Creek Forest and Seep	very high	very high
Island Creek Heath Bluff	very high	very high
NCDOT TIP: R-2824	very high	very high
Murrays Mill/Upper Balls Creek NA	very high	very high
Big Horse Creek Rare Plant Site	very high	very high
Broad River/Sandy Run NA	very high	very high
New Hope Springhead Swamp	very high	very high
Facebook Site	very high	very high
Davenport Road/Mountain View Rare Plant Site	very high	very high

Site Name	Current Resilience	Targeted Conservation
Broad River: Floyds Creek	very high	very high
Catawba River: Hoyle Crk-Micol Crk	very high	very high
South Fork Catawba R: Clark Crk, Miller Br, Cata Mem Hos	very high	very high
Buffalo Creek: Tributaries N and S of SR 2047	very high	high
Buffalo Creek: Kings Mountain Res	very high	very high
Broad River: Brushy Creek	very high	very high
Peaked Top Rare Plant Site/Foothills Landfill	very high	very high
Jacob Fork West Corridor	very high	very high
Floyds Creek Tributary Rare Plant Site	very high	very high
New Bethel Rare Plant Site	very high	very high
Leepers Creek Heartleaf Site	very high	very high
Cliffside Steam Station	very high	very high
Rhyme Conservation Preserve	very high	very high
Glade Creek, Alex County	very high	very high
Richardson Creek trib above Toms Lake	very high	very high
Gunpowder Creek: South of Hudson	very high	very high
Taylor Blaylock Res	very high	very high
Little Gunpowder Creek Rare Plant Site 1	high	high
Little Gunpowder Creek Rare Plant Site 2	high	high
Buffalo Creek Rare Plant Site	high	high
Northern Catawba County	high	high
Rock Barn Solar Farm	high	high
NCDOT TIP R-2824	moderate	moderate
Third Creek Rare Plant Site	moderate	moderate
Knob Creek NA	moderate	moderate
Buffalo Creek: Northeast of SR 1903	moderate	moderate
West Shelby Mesic Slope	moderate	low
Cat Square Heartleaf Forest	moderate	low
Kross Keys NA	moderate	moderate
First Broad River: Crooked Run Creek	moderate	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork	moderate	moderate
Catawba River Jacobs Fork and Camp Creek	moderate	moderate
Catawba River: North Fork Mountain Creek	moderate	moderate
Catawba River: Lake James	moderate	moderate
Hogpen Branch Transplant Site	moderate	moderate
Jonas Road Rare Plant Site	moderate	extirpated
South Fork Catawba River, Henry Fork	moderate	moderate
No Business Creek, Boyd Tract	moderate	moderate
Broad River/Sandy Run NA	moderate	moderate

Site Name	Current Resilience	Targeted Conservation
Buffalo Shoals Creek	moderate	moderate
Fox Knoll Farm	moderate	moderate
Forest City: Adj to Isothermal CC	moderate	moderate
Hickory Area	moderate	moderate
UT of Kings Mountain Res	moderate	moderate
Brushy Creek Headwaters	moderate	moderate
Smith Cliff/Henry Fork River	moderate	moderate
Simms Hill/Little River Uplands	moderate	moderate
Collinsville (Hughes) Creek Slopes	moderate	moderate
Burke County - Drowning Creek UT	moderate	moderate
Sandy Spring Church Springhead Swamp	low	low
First Broad River: Hickory Creek	low	low
Buffalo Creek: Ravine	low	extirpated
Buffalo Creek: Potts Creek	low	extirpated
Smith Cliff/Henry Fork River	low	low
Pott Creek	low	low
Northeast Lincoln: UT Walker Branch	low	extirpated
Gunpowder Creek	low	low
Killian Crossroads	low	low
Beaverdam Crk at First Broad River	low	low
Lincoln County, SR-1314	low	low
Levan Family Farm	low	low
Fanjoy Road Site	low	extirpated
First Broad River: Beaverdam Creek Tribs	low	low
South Mountains Pleasant Grove Uplands	low	low
NCDOT TIP R-3603A	low	low
Hickory Creek - UT (Shelby High School)	low	low
Boulder Creek Subdivision	low	low
Gateway Elementary School	low	low
First Broad River (North Carolina)	n/a	present
First Broad Hop-Hornbeam NA	n/a	present
Big Island Carolina Hemlock Bluff	n/a	present
Cherokee Creek/Bonner and Robin School Roads	n/a	present
Arrowood Branch	n/a	present
Cherokee Creek/SC 11	n/a	present

Viability Summary

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1282

1283 Urban development is predicted to have negative impacts on several of the current populations
 1284 under all of our scenarios. However, this loss of resilience and extirpation of a few populations
 1285 is offset by the fact that several additional populations were found to persist in the Status Quo
 1286 and Targeted Conservation scenarios. In the High Development Scenario, there is a predicted
 1287 loss of 6 populations, with loss of resilience in several additional populations. Regardless of the
 1288 scenario, the majority of the populations expected to persist on the landscape in 2040 are of at
 1289 least moderate resilience.

1290
 1291 Given the relatively high number of populations across each scenario, redundancy remains
 1292 similar to current conditions. That is to say, there appears to be adequate redundancy within the
 1293 range of dwarf-flowered heartleaf to withstand the impacts of localized press catastrophic
 1294 disturbances, however the species range is relatively small, making it potentially vulnerable to
 1295 long-term catastrophic events, such as climate change.

1296
 1297 Given that dwarf-flowered heartleaf has a very limited range, and after consulting with experts,
 1298 we decided delineating representative units was not appropriate for this species. It is worth
 1299 noting that in two of our scenarios (Status Quo and Targeted Conservation), additional
 1300 populations are found to persist in South Carolina, an area where we have relatively few current
 1301 populations. As discussed below, we believe there are opportunities to find additional
 1302 populations based on the amount of predicted unoccupied potential habitat. Although we did not
 1303 delineate representative units, we believe our scenarios do not predict declines in species
 1304 representation.

1305
 1306 **Table 6.10.** Viability summary for *Hexastylis naniflora* under 3 future scenarios (projected to
 1307 year 2040) and compared to Current Condition.

	CURRENT	STATUS Quo	HIGH DEVELOPMENT	TARGETED CONSERVATION
VERY HIGH	28	27	27	27
MODERATE	26	23	25	23
LOW	19	17	16	17

EXTIRPATED	n/a	5	6	5
PERSISTING	n/a	2	0	6
TOTAL	78	75	72	79

Opportunities for Additional Conservation

1311 Although our scenarios focus on areas where dwarf-flowered heartleaf have been found in the
1312 past, the Maxent model identifies a number of areas as high quality potential habitat for the
1313 species that falls outside the immediately known occurrence areas. A few of these areas are
1314 detailed below (Figure 6.2).
1315 1. West of the city of Lenoir, south of Highway 90/Adako Rd., north of Highway 64 within
1316 Caldwell County. This area identifies a large block of potential habitat. This area falls just
1317 outside the administrative boundary of the Pisgah National Forest. The bluffs and tributaries
1318 along the Johns River are identified as the best habitat, but there is also ample habitat identified
1319 along the forested areas of Celia, Husband, Abingdon and Greasy Creeks. The only known
1320 occurrence within this area is associated with Abingdon Creek and is under a conservation
1321 easement.
1322 2. Henry Fork River bluffs and tributaries east of Highway 18 within Burke County. A
1323 historic element occurrence is present by the Burke County line, but the entire area is identified
1324 as good quality potential habitat for the species where forested habitats remain.
1325 3. South West corner of Catawba County west of Highway 321. Several disjointed patches
1326 of high quality potential habitat are identified in this region associated with the river and creek
1327 slopes. Rock Creek, Jacob Fork River, Pott Creek, and their associated tributaries all contain
1328 blocks of potential habitat. A number of element occurrences are identified within this area, but
1329 additional habitat is identified both upstream and downstream of the known occurrences.
1330
1331 4. Clark, Pinch Gut, Maiden, and Allen Creeks, north of the town of Maiden. The slopes
1332 along these creeks all contain quality potential habitat. Known element occurrences are in the
1333 general area, but none are situated within the creeks listed.

1334	5.	First Broad River North of Highway 74, Rutherford County. Two older element
1335		occurrences are located within this area, however, the forested bluffs along the First Broad River
1336		and associated tributaries are identified as good quality potential habitat in many additional
1337		upstream and downstream areas in this system.
1338	6.	Hickory Creek, Sulphur Springs Branch (Little Hickory), Shoal Creek, and tributaries
1339		draining into First Broad River South of the Town of Shelby, north of the South Carolina border.
1340		The town of Shelby has likely disconnected this site from area 5 listed above. Here, slopes along
1341		the creeks and tributaries draining into the First Broad River are identified as potential habitat
1342		more so than the slopes along the First Broad River themselves. There is only a single element
1343		occurrence known upstream along Hickory Creek.
1344	7.	North Pacolet River and Obed Creek, north of where they join. The majority of potential
1345		habitat falls along the slopes of the North Pacolet River. Two older element occurrences (1991
1346		last observation) are found in the tributaries draining into the North Pacolet River, and many
1347		occurrences are found further upstream. The habitat model suggests that additional undiscovered
1348		habitat areas are present.
1349	8.	Pacolet River and Island Creek, north of Peters Creek, downstream of the Pacolet River
1350		dam. This area displays limited amounts of good quality potential habitat. Recent element
1351		occurrences are present in the upper headwaters of Peters and Zekial Creeks (Zekial Creek drains
1352		into Peters Creek) and in areas north of the Pacolet River dam, but none are known along the
1353		areas identified in this immediate area.
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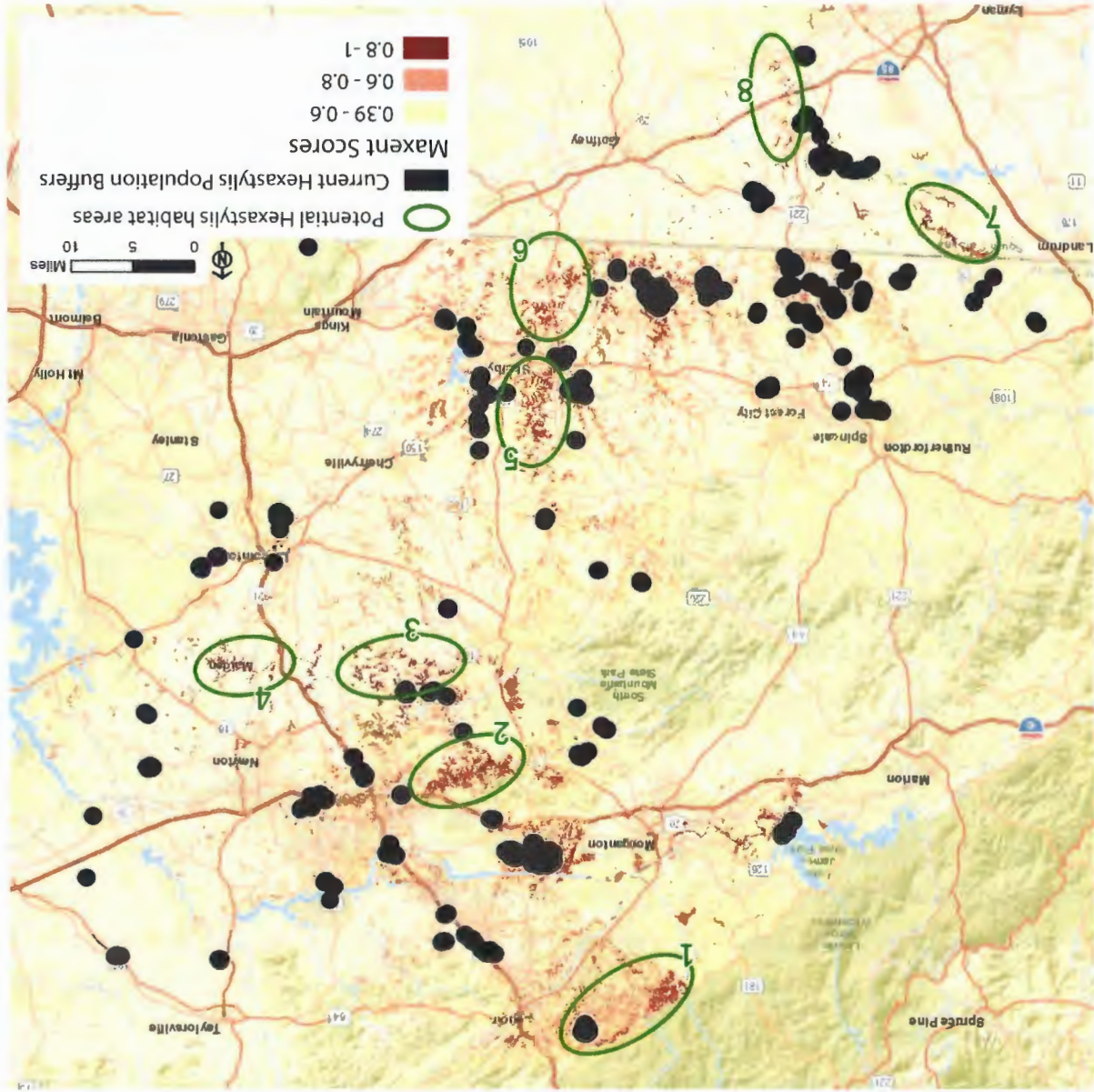


Figure 6.2. Areas identified as high quality potential habitat by Maxent model for *Hexastylis naniflora* that fall outside the immediately known occurrence areas.

1383	
1384	
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1411	
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From: [Marshall, Michael E](#)
To: [Reid, Rebekah N](#)
Subject: Re: SSA Comments from Janet
Date: Friday, May 18, 2018 8:42:37 AM
Importance: High

Hi Rebekah,

Just back from Biloxi at the Stewardship Partners meeting and catching up on emails.....I'll have a look at her comments asap. Thanks for sending along!

Mike

On Wed, May 16, 2018 at 10:51 AM, Rebekah Reid <rebekah_reid@fws.gov> wrote:

Hi Mike,

Janet asked to read the SSA and provide comments. Her comments are handwritten on the document so I scanned it (see attached). After trying to scan multiple times to get a complete document, it just wasn't cooperating so I gave up. The scanner made some of the pages black and skipped some pages but every page with a comment is there. Sorry that the scan is such a mess!

Overall, she said the first part was good but the second part with the stats was confusing. A lot of her comments have to do with clarification.

I'll be at NCTC next week (coincidentally for SSA training!) but will have access to email in the evening.

Thanks!

Rebekah Reid

US Fish and Wildlife Service
Asheville Ecological Services Field Office
160 Zillicoa St.
Asheville, NC 28801
phone: 828-258-3939 x238
cell: 828-782-0090

NOTE: This email correspondence and any attachments to and from this sender is subject to the Freedom of Information Act (FOIA) and may be disclosed to third parties.

--

Mike Marshall
SSA Program Specialist
U.S. Fish and Wildlife Service Region 4
Cell: 512-461-6217
Alternate email: mmarshall@ag.tamu.edu

Work Schedule 1st Week

Monday-Thursday --> In Office 7:30-4:30 CST

Work Schedule 2nd Week

Monday-Thursday --> In Office 7:30-4:30 CST

This email correspondence and any attachments to and from this sender is subject to the Freedom of Information Act and may be disclosed to third parties.

Chapter 1: INTRODUCTION

Disclaimer: THIS INFORMATION IS DISTRIBUTED SOLELY FOR THE PURPOSE OF PRE-DISSEMINATION PEER REVIEW UNDER APPLICABLE INFORMATION QUALITY GUIDELINES. IT HAS NOT BEEN FORMALLY DISSEMINATED BY THE USFWS. IT DOES NOT REPRESENT AND SHOULD NOT BE CONSTRUED TO REPRESENT ANY AGENCY DETERMINATION OR POLICY.

The dwarf-flowered heartleaf (*Hexastylis naniflora*) is a species of plant endemic to the upper Piedmont region of western North Carolina and upstate South Carolina. The dwarf-flowered heartleaf has been listed as threatened under the Endangered Species Act of 1973, as amended (Act), since 1989 (FR 54 14964-14967). The Species Status Assessment (SSA) framework (USFWS 2016, entire) summarizes the information compiled and reviewed by the US Fish and Wildlife Service (Service), incorporating the best available scientific and commercial data, to conduct an in-depth review of the species' biology and threats, evaluate its biological status, and assess the resources and conditions needed to maintain long-term viability. The intent is for the SSA to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from listing to consultations to recovery.

A Recovery Plan for the species was never completed. However, over the last 29 years, the Service has worked closely with partners to make significant progress toward recovery of the species. The Service is initiating this SSA to aid in determining the appropriateness of reclassifying the species. In the event that the SSA does not support reclassification, the SSA will be used to inform the development of a Recovery Plan. Importantly, the SSA does not result in a decision by the Service on whether this species should be proposed for reclassification under the Act. Instead, this SSA provides a review of the available information strictly related to the biological status of the dwarf-flowered heartleaf. The reclassification decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies. The results of a proposed decision will be announced in the *Federal Register*, with appropriate opportunities for public input.

For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in its natural systems over time. Using the SSA framework (Figure 1.1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (Wolf *et al.* 2015, entire).

- **Resiliency** describes the ability of populations to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health;



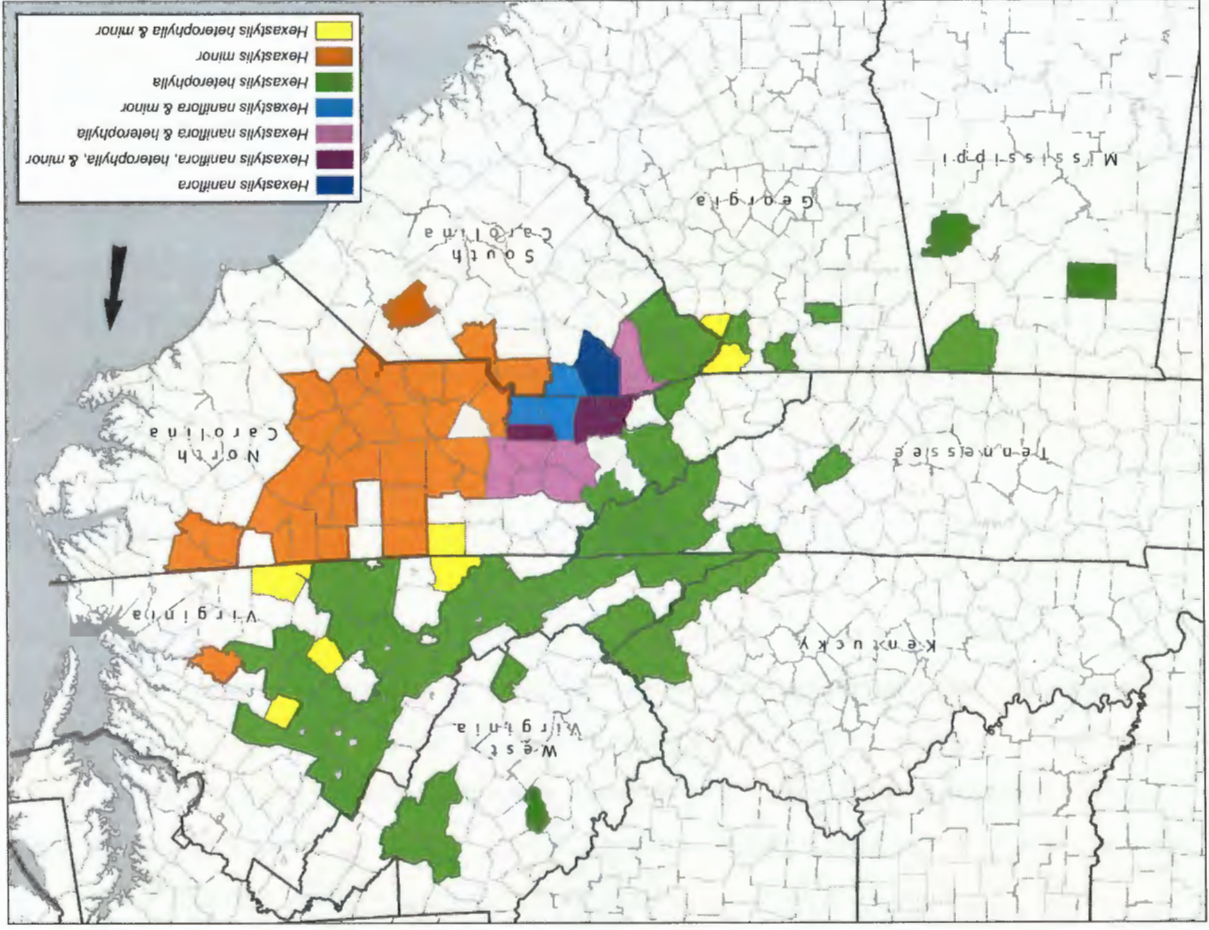
Figure 1.1. Species Status Assessment Framework

To evaluate the biological status of the dwarf-flowered heartleaf, both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation (together, the 3Rs). This SSA provides a thorough assessment of biology and natural history, and assesses demographic risks, stressors, and limiting factors in the context of determining the viability and risks of extinction for the species.

The format for this SSA includes: (1) Biology and Species Needs, (2) Current Conditions, (3) Influences on Viability, and (4) Future Conditions. This document is a compilation of the best available scientific and commercial information, and a description of past, present, and likely future risk factors to the dwarf-flowered heartleaf.

95 recognized as a genus (Niedenberger 2010). Additionally, most North American publications
 96 recognize *Hexastylis* at the generic level (Flora of North America 1997, Weakley 2015).

97
 98 The Service is not aware of any proposed changes in taxonomy that would affect the continued
 99 legal status of *H. naniflora* under the Act. However, within the range of *H. naniflora* there are
 100 populations which fall outside of the range of published values for key floral characteristics,
 101 overlapping with values described for *H. heterophylla* or *H. minor* (Figure 2.1; Weakley, 2010;
 102 Murrell et al. 2007; Gaddy 1987). These geographic areas of overlap in key characters have been
 103 the focus of recent genetic analyses (Murrell et al. 2007; Renninger, 2010; Murrell, 2015).



105 **Figure 2.1.** Distribution map showing county records for the three species in the *H. heterophylla*
 106 complex. Data was gathered from herbarium specimens, Element Occurrence Records (EORs)
 107 sheets and field studies. Based on Murrell et al. 2007.

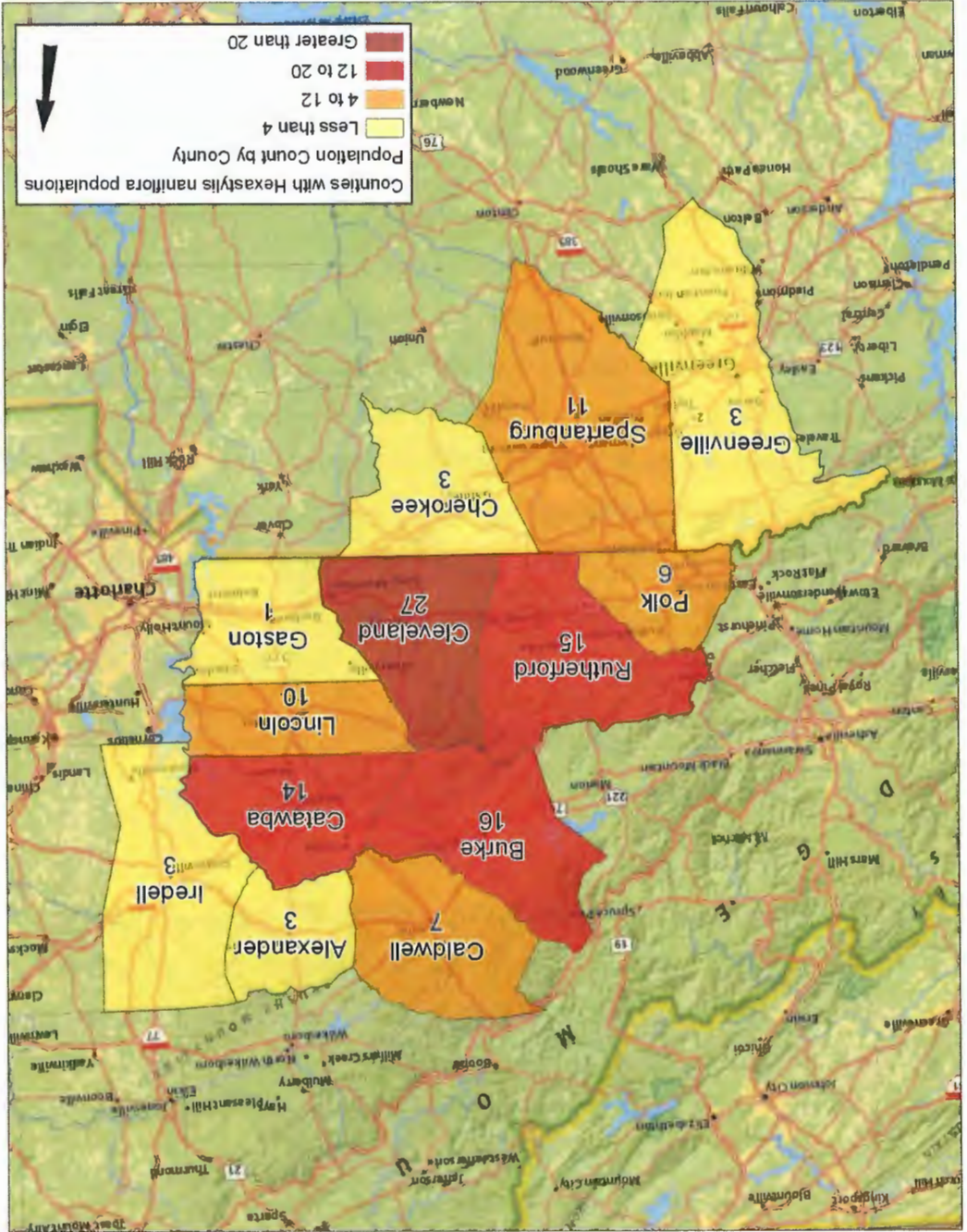


Figure 2.2. Current county distribution for dwarf-flowered heartleaf, with associated number of known populations within each county.

Many of those working with *Hexastylis naniflora* have used the terms “sub site”, “site”, “location”, “occurrence” (often, but not always, in reference to Natural Heritage Program Element Occurrence (EO) Records), “subpopulation” and “population” interchangeably. Others

176 three species within the Hexastylis Heterophylla subgroup (*H. heterophylla*, *H. naniflora*, and *H. minor*), which employ myrmecochory as a method for seed dispersal.

178
179 Ants appear to be a primary dispersal agent for the dwarf-flowered heartleaf (Gaddy 1986; Jones
180 et al. 2014). All diaspores of *Hexastylis naniflora* presented to ants (*Aphaenogaster ruidis*) were
181 quickly removed (Gaddy, 1986). This is not to say that they are not occasionally, or even
182 frequently, dispersed and/or pollinated by other means. Jones et al. (2014) suggests that the
183 pollination mechanism is facultative, benefiting from more than one method of
184 pollination/fertilization. Ants were the pollinators in a controlled experiment, and their data
185 supports that when outside molesting forces/pollinators (biotic and abiotic) were limited by their
186 caging procedure, the efficiency of pollination decreased by almost 50%, however, caged
187 flowers did produce seeds, indicating pollination occurred via some alternative method.

189 *Habitat*

190
191 Dwarf-flowered heartleaf appears to have a restricted range due to its habitat requirements. The
192 habitat where dwarf-flowered heartleaf exists is limited in size and scope due to a multitude of
193 factors including soil type, moisture availability, and slope aspect (Wagner 2013). This unique
194 combination of factors limits not only the range of dwarf-flowered heartleaf, but also the size of
195 a given population. With the limited range and size in populations, questions arise regarding
196 gene flow among populations. How much is occurring and how often does it occur? It is due, in
197 part, to narrow habitat requirements that conservation measures have been implemented for the
198 protection of the species. Any efforts made to protect this species must consider giving
199 protection to the available habitat.

200
201 Dwarf-flowered heartleaf occurs on piedmont uplands on acidic sandy-loam soils that are very
202 deep and moderately permeable (Gaddy 1981, 1987). Typical habitats for this species include
203 mesic to dry bluffs, slopes, or ravines in deciduous forests that are frequently associated with
204 *Kalmia latifolia* (Padgett 2004, Weakley 2015, USFWS 2015), or in moist soils adjacent to
205 creeks, streamheads, or along lakes and rivers. Plants have been observed to grow larger and
206 have more frequent flowering in floodplains along rivers, lakes, and streams (Newberry 1993).

Wagner (2013) conducted a habitat suitability study to quantify the habitat requirements for
 207
 dwarf-flowered heartleaf, which may be used for helping identify the species when not in flower
 208
 (relative to other *Hexastylis* species habitat preferences), find new populations, or identify
 209
 suitable sites for transplants.
 210
 211
 212
Soils
 213
 The species appears to be restricted to Pacolet sandy loam, Madison gravelly sandy loam, and
 214
 Musella fine sandy loam soils (Gaddy 1981, 1987). The species grows in acidic soils along bluffs
 215
 and adjacent slopes, in boggy areas next to streams and creekheads, and along the slopes of
 216
 nearby hillsides and ravines (Gaddy 1980, 1981). The plant is primarily found inhabiting north-
 217
 to northwest-facing slopes, bluffs, and ravines in close proximity to creeks or streams. Within
 218
 these areas exists the soil type required for *H. naniflora* to grow. It grows primarily on well-
 219
 drained, sandy, acidic soils, and will not grow in heavy clay (Gaddy 1981).
 220
 221
 The results of soil samples analyzed at the Clemson Soil Lab suggest that major differences in
 222
 soil chemistry exist between the species in the *H. heterophylla* complex (Murrell et al. 2007).
 223
 Statistical analysis of the soil samples showed that many of the basic elements were significantly
 224
 different among the three species. Those significant differences occurred in Phosphorous (P),
 225
 Potassium (K), Magnesium (Mg), Zinc (Zn), Manganese (Mn), (Na), Sodium, and Cation
 226
 Exchange Capacity (CEC). Slightly significant differences were seen in Buffer pH (Bu pH), and
 227
 228
 Acidity.
 229
 Soil chemistry showed marked differences between the species in the complex (Murrell et al.
 230
 2007). The results indicated that soil chemistry is very different between *H. naniflora* and *H.*
 231
minor localities. The results also show that *H. heterophylla* and *H. naniflora* are found in soils
 232
 where the chemistry is more similar, but still showed significant differences. It would appear that
 233
 differentiation in soil types could be used as a proxy for species delineation. The soil analysis
 234
 also indicates that soils must be considered when trying to select sites for relocation of imperiled
 235
 populations of *H. naniflora*.
 236
 237

238 Thirteen population sites in North Carolina and South Carolina were examined using the
 239 Carolina Vegetation Survey (CVS) method to compare species richness between the three
 240 species of the *Hexastylis heterophylla* complex (Murrell et al. 2007). The analysis did not show
 241 statistically significant differences among the three species in the *H. heterophylla* complex.
 242 However, *H. naniflora* appears to have an association with three oak species that is lacking in the
 243 other two species in the complex. There are a number of oak species (*Q. coccinea*, *Q. prinus* (*Q. montana*), and *Q. velutina*), that tend to co-occur with only *H. naniflora*, but are not present with
 245 the other two species in the complex. This may be the result of some microbial need or specific
 246 soil nutrient required for those species to occur in the same habitat.

247 Five

250 There are little data on the response to fire by *Hexastylis naniflora*, however, prescribed burns
 251 have been conducted within the population at Cowpens National Battlefield in Cherokee County,
 252 SC. Preliminary data at this site and recent annual monitoring data of this population support the
 253 theory that moderate controlled burns do not negatively affect this population (Walker et al.
 254 2009). Additionally, a dormant season wildfire in Caldwell County did not show evidence of
 255 negative impacts to a population in Caldwell County (USFWS 2010). Fire suppression could be
 256 a hazard to *H. naniflora* by allowing fire intolerant, nonnative and invasive plants to thrive, as
 257 well as the accumulation of thick duff or leaf litter that may shade low growing species (Wagner
 258 2013).

259 Genetics

262 Analyses on ecology, morphology, soil chemistry, pollen, and molecular genetics have been
 263 evaluated for *Hexastylis naniflora* to determine the boundaries within the *Hexastylis*
 264 *heterophylla* complex, which consists of *H. heterophylla*, *H. minor*, and *H. naniflora* (Murrell
 265 2015, Wagner 2013, Niedenburger 2010, USFWS 2010, Murrell et al. 2007, Padgett 2004).
 266 These analyses support the continued recognition of these taxa as well-defined, discrete species.
 267 Scanning electron microscopy (SEM) consistently distinguished *H. naniflora* from other
 268 members of the *H. heterophylla* complex based on pollen microscopy. Principal Components

269 Analysis of floral characters and soil chemistry also consistently distinguished *H. naniflora* from
 270 *H. minor* and *H. heterophylla*. However, efforts to obtain consistently distinct banding patterns
 271 using Inter Simple Sequence Repeats (ISSRs) were unsuccessful at distinguishing *H. naniflora*
 272 from other members of this group (Murrell et al., 2007). These results were based upon an
 273 extremely small sample size (n=10 *H. naniflora* individuals), and therefore warrant further
 274 investigation.

275
 276 Field observations demonstrate that there are some populations of dwarf-flowered heartleaf with
 277 morphological characteristics that do not fit within the range of published values for key traits,
 278 overlapping with values for *H. heterophylla* or *H. minor* (Gaddy 1987, Murrell et al. 2007,
 279 USFWS 2010, Weakley 2015). These populations with overlap in key characteristics were the
 280 focus of a genetic analysis conducted at Appalachian State University (ASU) through funding
 281 provided by NCDOT (Murrell 2015). In some populations, floral characteristics are highly
 282 variable, which suggests the potential for hybridization or individuals with highly variable flower
 283 size and shape (Murrell 2015). Additionally, no vegetative characters were previously known to
 284 consistently distinguish *Hexastylis naniflora* from other close relatives. Given the difficulties
 285 with field identification of the species, particularly when not in flower, this study sought to
 286 develop a microsatellite library of molecular markers to resolve variation in populations of
 287 dwarf-flowered heartleaf and apply the markers to populations with highly variable characters, as
 288 identified by NCDOT biologists. The morphological and micromorphological information from
 289 those variable populations were compared to molecular results with morphological,
 290 micromorphological, and distributional data to determine genetic structure, biological boundaries,
 291 and placement of putative hybrids or intermediate populations of *H. naniflora* (Murrell 2015).

292
 293 The preliminary findings of this study suggest that populations in the southern range of dwarf-
 294 flowered heartleaf exhibit a more uniform genetic pattern, with some possible hybridization with
 295 *H. minor*. Populations in the northern part of the range appear to have hybridized with both *H.*
 296 *heterophylla* and *H. minor*, although there are still individuals with “pure” *H. naniflora*
 297 genotypes in the northern range (Murrell 2015). It is critical to note that although these data
 298 provide anecdotal evidence of hybridization with the *Hexastylis heterophylla* group, intraspecific
 299 variation may be caused by forces other than hybridization, such as convergent morphological

300 evolution (Dobzhansky 1937), or the species is in the process of speciation and this study shows
 301 a case of incomplete speciation (Murrell 2015), and/or other environmental factors are at play
 302 (Wagner 2013). On May 11, 2016, a meeting was held with USFWS, NCNHP, NCDOT, and
 303 ASU to discuss the status of *H. naniflora* and the current work being conducted among the
 304 agencies (Amoroso 2016). Based on discussions during this meeting, the results of this study
 305 reported by ASU to NCDOT in 2015 are preliminary. Dr. Matt Estep (ASU) provided additional
 306 preliminary results to NCNHP in May 2016, showing which populations were sampled, sample
 307 size, and percent of samples that show evidence of hybridization, and hybridizing with which
 308 species. ASU continues to work towards a more definitive explanation of the variation in the *H.*
 309 *heterophylla* complex (Murrell 2015, Amoroso 2016).

311 CHAPTER 3: SPECIES NEEDS

312
 313 For the purpose of this report, we define viability as the ability of the species to sustain
 314 populations in the wild over time. Species with greater numbers (redundancy) of healthy
 315 populations (resiliency), encompassing a broad array of ecological and genetic diversity in a
 316 spatial arrangement that maintains adequate gene flow (representation), are more likely to be
 317 viable. Using the Species Status Assessment framework, we describe the species' viability by
 318 characterizing the status of the species in terms of its resiliency, redundancy, and representation.

320 *Delineating Populations*

321
 322 As stated in the USFWS five-year review, many of those working with dwarf-flowered heartleaf
 323 have used the terms "sub site," "site," "location," "occurrence" (often, but not always, in
 324 reference to Natural Heritage Program Element Occurrence Records), and "population"
 325 interchangeably, while others have aggregated sites into populations according to subjective
 326 criteria which have never been explicitly defined. This has generated considerable discrepancies
 327 among sources with respect to the number of known populations within a given area (or across
 328 the species' range), to the extent that numbers are not comparable from one source to the next.
 329 The tendency, in the past, to treat each location as a separate population also artificially inflated
 330 the actual number of populations known.

331 The Natural Heritage Program collects information on occurrences of rare plants, animals,
 332 natural communities, and animal assemblages. Collectively, these are referred to as "elements of
 333 natural diversity" or simply as "elements." Locations of these elements are referred to as
 334 "element occurrences" (EO records). In recent years, NatureServe and its member Natural
 335 Heritage Programs have devised mapping standards to balance the need for fine-scale, highly
 336 site-specific EO records (required for monitoring and management) with the need to aggregate
 337 these records in meaningful units of conservation interest that may approximate biological
 338 populations (NatureServe 2002). Since USFWS does not maintain its own database of known
 339 locations of *Hexastylis naniflora*, it regards the NHP databases as the best repository for this
 340 information (USFWS 2010).

341 We delineate populations for the purposes of this SSA according to the NatureServe (2002)
 342 convention. Separation distances are a key component to delineating populations from EO
 343 records. For the dwarf-flowered heartleaf, we used the EO Data Standard which provides a
 344 Default Separation Distance of 1 km (~0.62 miles) for plant and animal elements that lack EO
 345 specifications, noting that situations involving dispersal barriers could involve even shorter
 346 distances. While gene flow declines over distance at different rates for different elements, the
 347 minimum default EO separation distance of 1 km has been accepted by the Network as the most
 348 suitable round-number metric-system approximation broadly applicable to many (but not all)
 349 situations. This results in several dwarf-flowered heartleaf populations being stand-alone EOs,
 350 as well as many populations being aggregates of several EOs.

Population Resiliency

351 For the dwarf-flowered heartleaf to maintain viability, its populations or some portion thereof
 352 must be resilient. Stochastic factors that have the potential to affect dwarf-flowered heartleaf
 353 include impacts to its habitat, particularly human development pressures, but also climate change
 354 and presence of invasive species. Other factors that influence the resiliency of dwarf-flowered
 355 heartleaf populations include abundance within populations, and habitat factors such as
 356 elevation, slope, aspect, and soil type. Influencing those factors are elements of dwarf-flowered

heartleaf ecology that determine whether populations can grow to maximize habitat occupancy, thereby increasing resiliency of populations. These factors and habitat elements are discussed below (Figure 3.1).

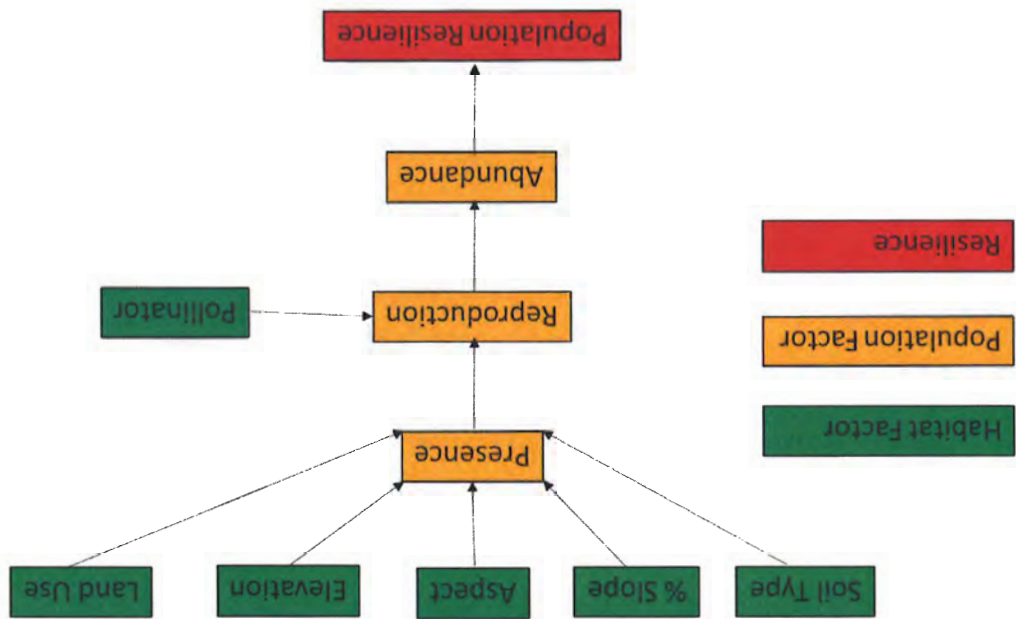


Figure 3.1. Conceptual diagram describing population and habitat factors influencing population resilience for dwarf-flowered heartleaf.

Habitat Factors: Slope, Aspect, Elevation, Soil, and Forest Type

A previous habitat suitability study attempted to quantify the habitat requirements for dwarf-flowered heartleaf (Wagner 2013). With this model in mind, and the input of species experts as to important habitat factors for the species, we used updated habitat data, as well as inclusion of updated EOs, to create a new habitat model to identify potential habitat throughout the species range. All source datasets and variables created are described in Appendix 3.

Source Data and Model Variables

Fifty-three, 10-digit hydrologic units (HUC) comprise the analysis extent (Figure 3.2). In North Carolina, it includes all 10-digit HUC that fall within the boundaries of 8-digit HUC with known occurrence of *Hexastylis naniflora*. In South Carolina, we also included all 10-digit HUC that

fell within the boundaries of 8-digit HUC with known occurrence of *Hexastylis naniflora*, but excluded the southern portions of the HUC-8 areas due to the boundaries being exceedingly large and far away from any known occurrences.

Hexastylis naniflora element occurrence data was obtained from the North Carolina Natural Heritage Program and the South Carolina Heritage Trust Program. Current populations of *Hexastylis naniflora* were identified by reviewing the last observed data in the database and excluding all populations that have not been observed since 2005 to remain consistent in our approach of assessing resiliency described previously. To represent these current population areas in Maxent, a raster cell center was retained for every 30 x 30 meter pixel that was situated within the current element occurrence data polygons.



Figure 3.2. Analysis extent of the habitat model for *Hexastylis naniflora*. Red line indicates Maxent analysis extent, blue lines are 8-digit HUC boundaries, black lines are 10-digit HUC boundaries. The orange line in the inset map indicates where the analysis extent is situated in North and South Carolina

Model Development

We used Maxent software (version 3.4.1) for species habitat modeling (Phillips et al., 2018). An initial single model Maxent run was done to determine which variables could be excluded due to limited percent contribution to the model. Any variable that contributed less than 1% to the single model run results was excluded in the final model. The following variables were excluded: landcover diversity, canopy height, SSURGO drainage class, SSURGO hydrologic group, aspect 9-class, slope 5-class, solar radiation, and maximum annual temperature. It is interesting to note that a previous habitat modelling effort (Wagner 2013) included aspect and slope, whereas the Maxent model excluded these variables. This does not mean these variables are not important components of dwarf-flowered heartleaf habitat, but rather these variables did not significantly improve the model. Also, landform data was included, and perhaps landform, which includes components of aspect and slope combined is a more meaningful variable than aspect or slope independently.

For the final model, a 10-run replicate Maxent model was created using cross-validation. For replicate models, the occurrence data is randomly split into a number of equal-sized groups called "folds", and separate models are created leaving out each fold in turn. The individual model runs are then averaged together to derive the final model.

Results

Figure 3.3 shows the model output. The minimum cutoff value (to determine if an area is considered potential habitat for a species) of 0.39 was determined by using the average 10th percentile training presence. The 10th percentile training presence uses the suitability threshold associated with the presence record that occurs at the 10th percentile of presence records (Phillips 2018). This value excludes some of the outlier population areas in the Maxent

425 predictions to focus on the typical habitat conditions for this species. The total area ranked
 426 greater than 0.39 in the Maxent model was just 6.00% of the total analysis area (Table 3.1).

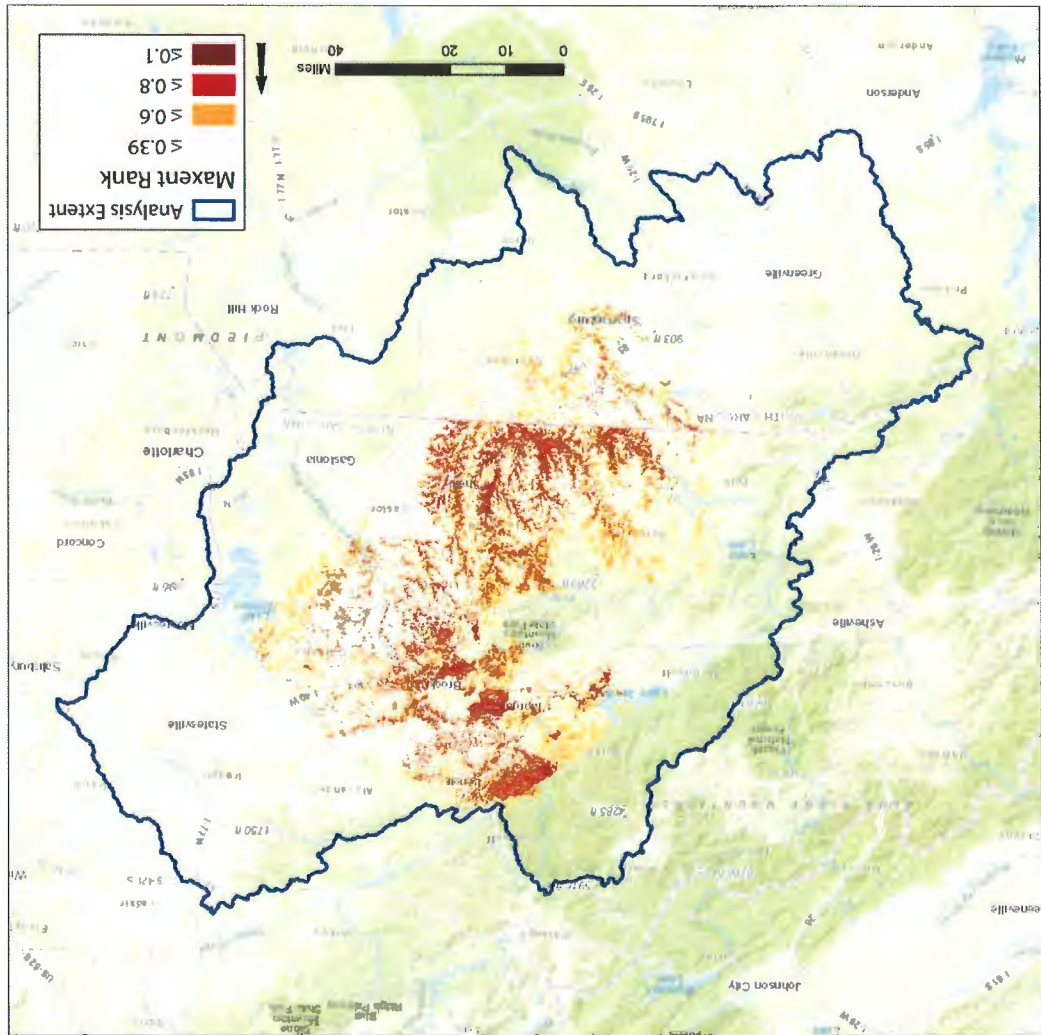


Figure 3.3. Maxent model output map

Table 3.1-Area estimates of the Maxent model

Maxent Score	Acres	Square Miles	Percent of Total
0.39 and greater	302,834.13	473.18	6.02%
0.6 and greater	128,273.52	200.43	2.55%
0.8 and greater	22,115.97	34.56	0.44%

432 The average area-under-curve (AUC) score for the replicate Maxent model is 0.86. The AUC is
 433 calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1
 434 and may be interpreted as a single test statistic that assesses model performance, indicating the
 435 ability of the model to correctly classify the occurrence data used. The model performed well in
 436 its predictions, with a mean AUC of 0.86 (AUC value of 0.5 is no better than random; $AUC < 0.5$
 437 is worse than random; $AUC > 0.5$ is greater predictive power than random; Baldwin 2009).

438 The Maxent output supplies estimates of the relative contributions of the environmental variables
 439 to the Maxent model (Table 3.2). SSURGO map unit key) is the top contributing variable. One

440 hundred and thirty-five individual soil types are present within the polygon boundaries of the
 441 *Hexastylis naniflora* element occurrences. Many of these individual soil types are part of soil
 442 complexes and are separated by things such as percent slope, erosion, how stony/rocky, and
 443 amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25
 444 to 60 percent slopes, very stony (14.1% of total). However, collectively the Meadowfield soils
 445 only comprised 14.3% of all soils). The individual Pacolet soil types were very common and
 446 collectively comprise 36% of all soil types present. Woolwine, Rion, and Fairview soils were
 447 also collectively common, comprising 10.4%, 9.7%, and 8.8% of all soils present respectively.

Table 3.2. Percent contribution of the environmental variables

Environmental Variable	Percent Contribution
SSURGO map unit key	23.5%
Minimum Annual Temperature	17.8%
Average Annual Precipitation	15.7%
Landcover	12.9%
Landcover Majority	12.0%
Landcover Hexastylis Grouping	5.4%
Geomorphons	4.9%
Elevation	4.6%
Canopy Cover	3.2%

SSURGO is the
 what is the
 SSURGO? Please explain

can you explain what does the
 variable describe

452 The minimum annual average temperature range in the analysis is 39 – 51 degrees Fahrenheit. The majority of the *Hexastylis naniflora* element occurrences (89%) are found at the 47 and 48 degrees. The average annual precipitation range in the analysis is 42 – 81 inches per year. The majority of the *Hexastylis naniflora* element occurrences (82%) are found in the 47 – 49 inches per year range.

457

458 Piedmont forested landscape habitats dominate the land area of the element occurrences.

459 Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier (53%), Southern Piedmont Mesic Forest (9%), Southern Piedmont Dry Oak-Pine Forest (5.2%), Southern Piedmont Small Floodplain and Riparian Forest (4.4%), and collectively comprise 71% of the element occurrences area. Evergreen Plantation or Managed Pine (9%), Harvested Forest (7.2%), Developed, Open Space (5%), Pasture/Hay (2.1%) collectively comprise 22% of the total element occurrence area. The remaining 6 percent of element occurrence area is comprised of a mix of 14 other natural and disturbed landscape classes, but each at small percentages.

466 The landscape majority classification scheme reduces the total number of landscape classes present in the analysis extent from 23 to 11. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landscape class (58%). However disturbed categories are increased in area (sum total of 35%). Evergreen plantation or managed pine (12%) and Pasture/Hay (12%) are the only other categories that have at least 10% or greater area. The increase in disturbed landscape area representation in the landscape majority layer suggests that many *Hexastylis naniflora* population areas are situated in areas impacted by disturbed landscape. This is likely due to urban encroachment and increasing fragmentation of habitats.

473 The landscape *Hexastylis naniflora* grouping reveals the amount of disturbance present in *Hexastylis naniflora* population areas. Landscape classes grouped as disturbed comprises 27% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, pasture/hay 12%, and hardwood forest 2%. Open water, evergreen and barren landscape groupings are all at less than 1% each.

480 Geomorphons revealed that the majority of *Hexastylis naniflora* element occurrence areas are situated in concave landforms. Geomorphon categories hollow (13%), valley (46%), and

How can we make out survey data? surveys required of development have been good the surveys is where all or that this

depression (10%) collectively comprise 69% of all *Hexastylis naniflora* population areas. Flat

landforms comprise 15.5% of the area and convex landforms the remaining 15.5%.

Within the analysis extent, the range of elevation present is 335 – 5,265 feet. For *Hexastylis*

naniflora, the prime elevation range is from 666 – 908 feet (53% of total element occurrence

area). A lesser elevation range is present from 935 – 1,184 (37% of total element occurrence

area).

Canopy cover for the *Hexastylis naniflora* populations are dominated by Tree Cover 70-80% (20.2%) and Tree Cover 80-90% (63.9%). The rest of the canopy cover categories are 2% or

less.

We performed a Kruskal-Wallis 1-way non-parametric Analysis of Variance (ANOVA) to investigate the relationship between Maxent scores and current resilience of populations (Table 3.3). There are significant differences in the average Maxent scores between the four resilience categories ($p = 0.04$) and the mean Maxent score increases as population resilience increases from low to very high. The model gives us some predictive ability regarding habitat suitability where higher Maxent scores, on average, result in higher population resilience.

So what does this mean? Hee we strongly suggest we simplify saying that higher resiliency are more resilient? Please dumb it down a little.

relationships between Maxent scores and current resilience groups for dwarf-flowered heartleaf.

Groups	Count	Mean Rank
low	13	30.7
moderate	25	30.7
high	5	42.8
very high	28	45.7

Source of Variation	SS	df	MS	F	P-value
Between Groups	4375.7	4	1093.92	2.65	0.0404

504	Total	32412.0	72
505			
506	<i>Reproduction and Presence of Pollinators</i>		
507			
508	The pollination of <i>Hexastylis</i> has not been well studied but the genus is thought to be pollinated		
509	by insects including flies, wasps, and thrips (Otte 1977). Additionally, Lengyel et al. (2010)		
510	described how, within the family Aristolochiaceae, more than 50% of the plant lineage is		
511	myrmecochorous (seed dispersal via ants). This supports Gaddy's work (1986), which found		
512	three species within the Hexastylis Heterophylla subgroup (<i>H. heterophylla</i> , <i>H. naniflora</i> , and <i>H.</i>		
513	<i>minor</i>), which employ myrmecochory as a method for seed dispersal.		
514			
515	Because the flower for this species is oftentimes partially or completely covered with soil and		
516	leaf litter, possibly inhibiting pollinator activity (Gonzalez 1972), there is still uncertainty in the		
517	pollination mechanism for dwarf-flowered heartleaf. Otte (1977) suggests that a variety of		
518	possible pollinators reside in this leaf litter, however, the calyx opening is considered to be far		
519	too small for efficient pollinating (Gaddy 1981). There are, however, invertebrates within this		
520	proposed size limit that could theoretically act as pollinators. It is possible that the species		
521	employs self-pollination, with or without a vector, or that cross-pollination occurs by a number		
522	of invertebrates. Jones et al. (2014) investigated pollination of dwarf-flowered heartleaf under a		
523	manipulative experimental design, and found that while insects may play a significant role in		
524	pollination, even without them, flowers managed to produce a partial seed set. However, two		
525	points need to be considered here. First, although flowers managed to produce seeds in the		
526	absence of insect pollinators, the efficiency of pollination decreased by almost 50%. Also, even		
527	if successful pollination occurs in the absence of insect vectors, the dispersal of plants amongst		
528	populations would be limited, and could result in decreased resilience due to genetic concerns		
529	such as limited gene flow and issues associated with potential inbreeding depression.		
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531	<i>Abundance</i>		
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532 The influence of stochastic variation in demographic (reproductive and mortality) rates is much
 533 higher for small populations than large ones. Stochastic variation in demographic rates causes
 534 small populations to fluctuate randomly in size. In general, the smaller the population, the greater
 535 the probability that fluctuations will lead to extinction. There are also genetic concerns with
 536 small populations, including reduced availability of compatible mates, genetic drift, and
 537 inbreeding depression. Small populations of dwarf-flowered heartleaf have low resilience,
 538 leaving them particularly vulnerable to stochastic events.

540 As of 2016, the combined databases of the NCNHP and SCDNR contain 239 Element
 541 Occurrence Records (EORs) for *H. naniflora* (NCNHP 2016, SCDNR 2016). These EORs depict
 542 roughly 113 locations which are sufficiently geographically distinct to be regarded as proxies for
 543 populations of the species (See *Delineating Populations*). Thus, the total number of populations
 544 has increased more than four-fold (from 24 to 113) since the species was listed in 1989.

546 At this time, the largest known populations have been monitored by NCNHP and NCDOT. The
 547 estimates for entire populations are based on a consistent monitoring methodology developed by
 548 NCDOT, USFWS, and NCNHP with monitoring plots representing roughly 10% of a population.
 549 Populations were delineated to get a more accurate boundary and size of the area occupied. All
 550 rosettes are counted annually in each monitoring plot to estimate an extrapolated population size,
 551 based on the number and density in the plots. As a result of these efforts, better estimates of
 552 population sizes for the largest known populations are available, compared to when the last five-
 553 year review was completed in 2010 (Robinson and Padgett 2016).

555 The 113 EORs have been estimated to contain anywhere from a single rosette to over 100,000
 556 rosettes. Appendix 1 was created by NCNHP (2016) to replicate the same format and population
 557 data as Table B2 of the most recent USFWS five-year review of *H. naniflora* (USFWS 2010), for
 558 comparison of changes since 2010, and summarizes the largest occurrences of *H. naniflora*, with
 559 the size of the population based on the number of rosettes it was last estimated to contain. The
 560 number of populations estimated to contain over 1,000 rosettes is 26. This is approximately 23%

562 of the total known populations and many of these populations contain well over 1,000
 563 individuals.
 564
 565 There are, however, 13 populations (12% of all known) that are simply known to be extant, with
 566 no available estimate of population size (NCNHP 2016, SCDNR 2016). If the most recent
 567 population estimates for each EOR are compiled across years of observation, the 13 populations
 568 could conservatively be estimated to contain a collective total of more than 300,000 rosettes
 569 (NCNHP 2016, SCDNR 2016).

Population Trends

572
 573 Although abundance is critical in assessing the resilience of dwarf-flowered heartleaf, trends in
 574 population growth can also be informative. Long-term growth trends are typically defined as the
 575 degree of change in population size over 200 years, whereas short-term growth is typically
 576 measured as that degree of change over a 10 year period. We lack a robust data set to assess
 577 trends at either of these time scales. However, from 2012-2016, NCNHP conducted systematic
 578 annual surveys of thirteen of the largest populations across the range.

580 Based on the results of the five-year monitoring efforts completed in 2016, nine out of thirteen
 581 populations remain stable during the five years of data collection (Robinson and Padgett 2016).
 582 The largest known population, Broad River: Henson's Creek, Brice, & Sandy Mush Outcrop in
 583 Rutherford County, NC, is estimated to have over 100,000 rosettes (Robinson and Padgett 2016).
 584 This large population consists of many scattered subpopulations on private property; two of the
 585 subpopulations are protected as a Registered Heritage Area, although Registry is a non-binding
 586 agreement with landowners that can be cancelled at any time (NCNHP 2018).

588 Two of the thirteen populations increased in numbers from 2012-2016: Cliffside Steam Station
 589 and Broad River: Floyds Creek, Long Branch. The Cliffside Steam Station is protected with a
 590 voluntary agreement with Duke Energy and was estimated to contain over 39,000 rosettes in
 591 2016. The Broad River: Floyds Creek, Long Branch population is not at all protected, but was
 592 last estimated to consist of over 12,000 individuals in 2016 (Robinson and Padgett 2016).

593 Based on the results of recent surveys and a review of all known populations of *Hexastylis*
594 *naniflora*, the overall trend over approximately 30 years is estimated to be declining 10-30%.
595 This is estimated by a combination of documented declines of some populations, while many
596 others appear to be remaining relatively stable, and some have increased.

597 Chapter 4: CURRENT CONDITIONS

600
601 Below we assess current resilience, representation, and redundancy as they relate to population
602 and habitat factors known to be important for species viability. Based off of recent reports
603 (Robinson and Padgett 2016; Robinson 2016), the species consists of 119 populations distributed
604 across 12 counties in North Carolina and South Carolina. Populations are composed of both
605 multiple EOs and stand-alone EO records. Recent genetic research discussed in Chapter 2,
606 suggests that dwarf-flowered heartleaf, as originally described, is found in the southern portion
607 of its presumed range based on current EO locations, and the northern portion could be a
608 currently undescribed species (Figure 4.1; Estep pers. Comm. 2018). The genetic analysis to
609 support this is complete, but a review of the morphology is ongoing and a new species has not
610 yet been described (Estep pers. Comm. 2018). For the purpose of this SSA, we assume all EO
611 detections are *H. naniflora*, and represent the best currently available scientific data.

Inconsistent with p. 27 (113)
Which says 119 pop's.

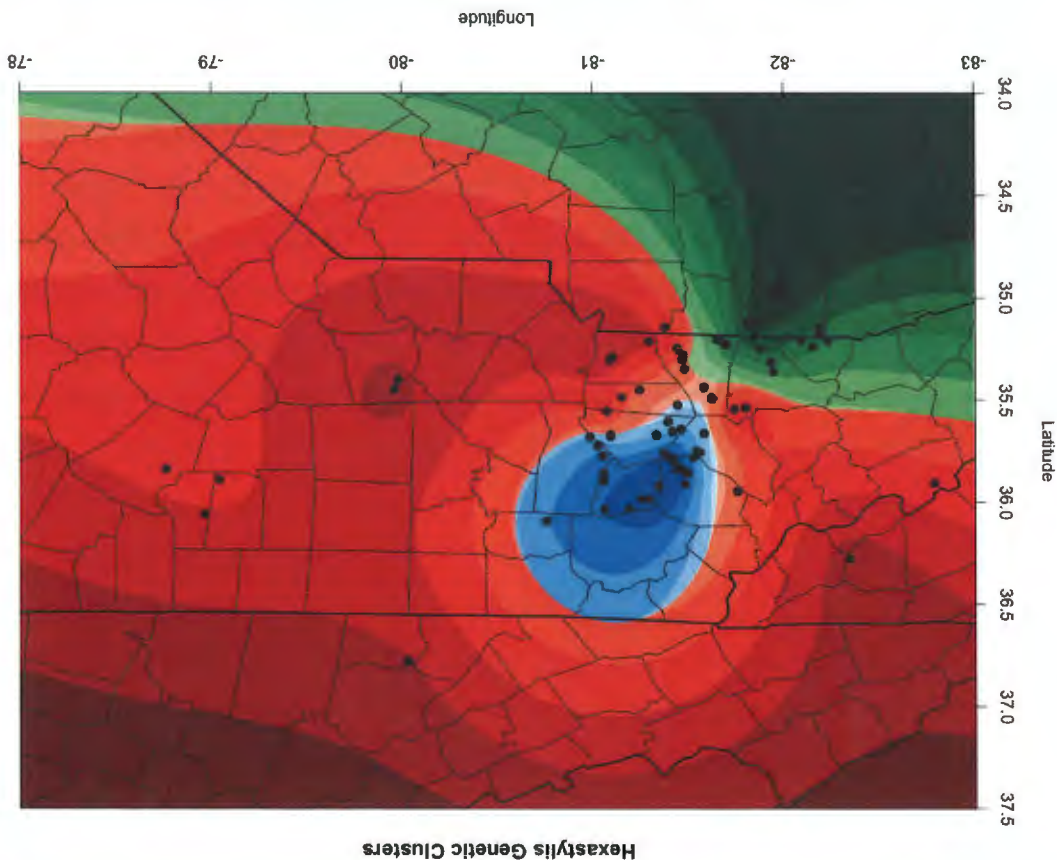


Figure 4.1. Recent genetic analyses detailing clustering of the genus *Hexastylis*. Black dots represent GIS locations of individual plants included in the genetic analysis. Green areas represent "true" *H. naniflora*; Blue represents a possible new species; Red represents other species in the genus (*H. minor*, *H. heterophylla*, etc.).

Current Population Resilience

Categorizing Resilience

For the purposes of this SSA, we use population size as the main driver of population resilience. The unit of measurement for population size in this species is a "clump" (rosette). As discussed previously, populations in North Carolina were delineated by NCNHP, whereas the Service defined populations in South Carolina. These delineations were based off of NatureServe criteria such as EO separation distance and intervening landscape matrix. EO data included a wide range

628 of years since the species was last observed at a given location (1964-2017), so although recent
629 reports suggest the species consists of 113 populations, some of that data is fairly outdated. For
630 the purposes of this SSA, we only used EOs that were observed since 2005. We did this for
631 several reasons. First, we did not want to go back too far and assume a population was still
632 present. Second, we wanted to be consistent in what we considered "current" for both
633 categorizing resilience and use in the habitat model (discussed later). Also, experts concurred
634 that records as old as 12 years are still likely to persist. Finally, there was a natural break in the
635 data at the year 2005, coinciding with the year the last five-year review was initiated, where the
636 number of EOs dropped off significantly in the years 2004 and earlier. It is important to note
637 that many of the populations that we excluded from our analysis may still persist on the
638 landscape. In fact, many EOs for this species have persisted for decades, despite not having
639 intervening surveys to confirm their persistence.

640

641 Based on the criteria (excluding EOs prior to 2005), there are currently 78 populations
642 distributed across the range of dwarf-flowered heartleaf, although this may be an underestimate
643 as discussed above.

644

645 To determine overall resilience for populations, we used EO viability ranks and expert opinion to
646 bin population size classes into corresponding resilience categories. EO viability ranks for the
647 species include excellent, good, fair, poor, extant, historical, and failed to find. The primary
648 factor in determining these ranks is EO size (as quantified by number of clumps). Condition of
649 habitat (vegetation community and structure) and landscape context (extent of suitable habitat
650 and physical factors) are also incorporated secondarily. Appendix 2 shows the NCNHP EO rank
651 specifications for dwarf-flowered heartleaf. The EO rank specifications suggest good-excellent
652 viability for populations consisting of at least 500 individuals, given there is sufficient high
653 quality habitat; fair viability for populations consisting of 100-500 individuals, depending on
654 habitat conditions; poor viability for populations consisting of less than 100 individuals. Recent
655 reports (Robinson 2016; Robinson and Padgett 2016) focus monitoring studies on populations
656 with greater than 1,000 individuals, populations that are assumed to be very viable. Because we
657 do not have habitat level information for every population we assessed, we synthesized all of the
658 above population size information and created four resilience categories as follows:

- Very high—populations with >1,000 individuals; very high probability of persistence for 20-30 years at or above the current population size.
- High—populations with 500-1,000 individuals; moderate-high probability of persistence for 20-30 years at or above the current population size.
- Moderate—populations with 100-500 individuals; low probability of persistence for 20-30 years at or above the current population size.
- Low—populations with <100 individuals; low probability of persistence for 20-30 years at or above the current population size, and moderate-high probability of extirpation.

Occupancy and Abundance

There are 78 populations of dwarf-flowered heartleaf that have been observed since 2005 (Table 4.1), and resilience of these populations is as follows: 28 (very high); 5 (high); 26 (moderate); 19 (low). Table 4.2 shows the contribution of each resilience category as follows: 36% (very high); 7% (high); 34% (moderate); 23% (low). When looking at cumulative percentages of resilience, it is interesting to note that 77% of all of the populations are classified as moderate to very high resilience (Table 4.2).

Table 4.1. Current populations of dwarf-flowered heartleaf and associated resilience across the species range. Abundance and last observation date based on Natural Heritage Program data (2018).

Site Name	State	County	Last Observed	Total plants	Resilience
Glade Creek, Alex County	NC	Alexander	2017	>1000	very high
Catawba River: Hoyle Crk-Micol Crk	NC	Burke	2013	>1000	very high
Island Creek Heath Bluff	NC	Burke	2016	>1000	very high
Gunpowder Creek: South of Hudson	NC	Caldwell	2012	>1000	very high
Peaked Top Rare Plant Site/Foothills Landfill	NC	Caldwell	2014	>1000	very high
Jacob Fork West Corridor	NC	Catawba	2012	>1000	very high
Murrays Mill/Upper Balls Creek	NC	Catawba	2013	>1000	very high
NC DOT TIP: R-2824	NC	Catawba	2015	>1000	very high
South Fork Catawba R: Clark Crk, Miller Br, Cata Mem Hos	NC	Catawba	2013	>1000	very high
Cowpens NBF - Site 1	SC	Cherokee	2016	>1000	very high

Site Name	State	County	Last Observed	Total plants	Resilience
Cliffside Steam Station	NC	Cleveland/Rutherford	2016	>1000	very high
Broad River/Sandy Run NA	NC	Cleveland	2012	>1000	very high
Broad River: Brushy Creek	NC	Cleveland	2016	>1000	very high
Buffalo Creek: Kings Mountain Res	NC	Cleveland	2016	>1000	very high
Buffalo Creek: Tributaries N and S of SR 2047	NC	Cleveland	2012	>1000	very high
Rhyme Conservation Preserve	NC	Lincoln	2016	>1000	very high
Mill Creek Forest and Seep	NC	Polk	2016	>1000	very high
New Hope Springhead Swamp	NC	Polk	2016	>1000	very high
Big Horse Creek Rare Plant Site	NC	Rutherford	2015	>1000	very high
Broad River: Floyds Creek	NC	Rutherford	2016	>1000	very high
Davenport Road/Mountain View Rare Plant Site	NC	Rutherford	2016	>1000	very high
Facebook Site	NC	Rutherford	2016	>1000	very high
Floyds Creek Tributary Rare Plant Site	NC	Rutherford	2012	>1000	very high
New Bethel Rare Plant Site	NC	Rutherford	2015	>1000	very high
Richardson Creek trib above Toms Lake	NC	Rutherford	2016	>1000	very high
DNR Peters Creek Heritage Preserve	SC	Spartanburg	2016	>1000	very high
Taylor Blalock Res	SC	Spartanburg	2016	>1000	very high
Leepers Creek Heartleaf Site	NC	Lincoln	2006	>1000	very high
Little Gunpowder Creek Rare Plant Site 1	NC	Caldwell	2015	500-1000	high
Little Gunpowder Creek Rare Plant Site 2	NC	Caldwell	2015	500-1000	high
Northern Catawba County	NC	Catawba	2017	500-1000	high
Rock Barn Solar Farm	NC	Catawba	2010-2011	500-1000	high
Buffalo Creek Rare Plant Site	NC	Cleveland	2012	500-1000	high
Third Creek Rare Plant Site	NC	Alexander	2010	100-500	moderate
Hickory Area	NC	Burke/Catawba/Caldwell	2016	100-500	moderate
Burke County - Drowning Creek UT	NC	Burke	2017	100-500	moderate
Simms Hill/Little River Uplands	NC	Burke	2015	100-500	moderate
Smith Cliff/Henry Fork River	NC	Burke	2015	100-500	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork Catawba River Jacobs Fork and Camp Creek	NC	Catawba	2016	100-500	moderate
NCDOT TIP R-2824	NC	Catawba	2015	100-500	moderate
South Fork Catawba River, Henry Fork	NC	Catawba	2007	100-500	moderate
Broad River/Sandy Run NA	NC	Cleveland	2012	100-500	moderate
Brushy Creek Headwaters	NC	Cleveland	2014	100-500	moderate
First Broad River: Crooked Run Creek	NC	Cleveland	2010	100-500	moderate
No Business Creek, Boyd Tract	NC	Cleveland	2007	100-500	moderate

Site Name	State	County	Last Observed	Total plants	Resilience
West Shelby Mesic Slope	NC	Cleveland	2016	100-500	moderate
UT of Kings Mountain Res	NC	Gaston	2012	100-500	moderate
Buffalo Shoals Creek	NC	Iredell	2014	100-500	moderate
Cat Square Heartleaf Forest	NC	Lincoln	2012	100-500	moderate
Collinsville (Hughes) Creek Slopes	NC	Polk	2016	100-500	moderate
Fox Knoll Farm	NC	Polk	2016	100-500	moderate
Forest City: Adj to Isothermal CC	NC	Rutherford	2010	100-500	moderate
Jonas Road Rare Plant Site	NC	Rutherford	2014	100-500	moderate
Knob Creek NA	NC	Cleveland	2005	100-500	moderate
Buffalo Creek	NC	Cleveland	2005	100-500	moderate
Kross Keys NA	NC	Polk	2005	100-500	moderate
Catawba River: North Fork	NC	Catawba	2005	100-500	moderate
Mountain Creek	NC	Burke	2006	100-500	moderate
Hogpen Branch Transplant Site	NC	Rutherford	2005	100-500	moderate
NCDOT T1P R-3603A	NC	Alexander	2017	<100	low
South Mountains Pleasant Grove	NC	Burke	2016	<100	low
Uplands	NC	Burke	2016	<100	low
Gunpowder Creek	NC	Caldwell	2012	<100	low
Killian Crossroads	NC	Catawba	2010	<100	low
Pott Creek	NC	Catawba	2012	<100	low
Beaverdam Ck at First Broad River	NC	Cleveland	2011	<100	low
Buffalo Creek: Potts Creek	NC	Cleveland	2012	<100	low
Buffalo Creek: Ravine	NC	Cleveland	2007	<100	low
Hickory Creek - UT (Shelby High School)	NC	Cleveland	2016	<100	low
Boulder Creek Subdivision - Jordan Road	SC	Greenville	2016	<100	low
Gateway Elementary School	SC	Greenville	2017	<100	low
Fanjoy Road Site	NC	Iredell	2015	<100	low
Levan Family Farm	NC	Iredell	2013	<100	low
Lincoln County, SR-1314	NC	Lincoln	2014	<100	low
Northeast Lincoln: UT Walker Branch	NC	Lincoln	2009	<100	low
Sandy Spring Church Springhead Swamp	NC	Polk	2005	<100	low
First Broad River: Hickory Creek	NC	Cleveland	2006	<100	low
Smith Cliff/Henry Fork River	NC	Burke	2005	<100	low
First Broad River: Beaverdam Creek Tribs	NC	Cleveland	2006	<100	low

Table 4.2. Population resilience categories by county for dwarf-flowered heartleaf.

County	Very High	High	Moderate	Low	Totals
Alexander	1		1	1	3
Burke/Catawba/Caldwell			1		1
Burke	2		4	2	8
Caldwell	2	2		1	5
Catawba	4	2	4	2	12

Cherokee	1				
Cleveland/Rutherford	1				1
Cleveland	4	1	7	6	18
Gaston			1		1
Greenville				2	2
Iredell			1	2	3
Lincoln	2		1	2	5
Polk	2		3	1	6
Rutherford	7		3		10
Spartanburg	2				2
Totals	28	5	26	19	78
% of total	36	7	34	23	100
Cumulative %	40	43	77	100	--

Population Trends

Although we lack an adequate past time series of abundance data for all populations to estimate growth rates or population trends, NCNHP conducted surveys of thirteen of the largest populations across the range of the species from 2012-2016. Table 4.3 shows the results of all of these surveys. Two populations show an increasing trend, nine show a stable trend, and two show a decreasing trend.

Table 4.3. Summary of population trends over 5 years of monitoring data for 13 of the largest populations of dwarf-flowered heartleaf across its range (from: Robinson and Padgett 2016).

Trend	Survey	Site	2016 estimated number of plants (Rosettes)	2016 area occupied (Acres)
Increasing	NCNHP	Cliffside Steam Station (EO 276)	39,535	52
	NCNHP	Broad River: Floyds Creek, Long Branch (EO 177)	12,687	5.67
Stable	NCNHP	Island Creek Bluff/Love Lady Site (EO 029)	50,481	61.76
	NCNHP	Rhyme Preserve (EO 302)	19,873	22.43
	NCNHP	Mills Creek Forest and Seep (EO 023)	1,733	1.39
	NCNHP	New Hope Springhead Swamp (EO 125)	12,235	5.03

722 has the potential to negatively influence population resiliency outside of normal environmental
723 and demographic stochasticity. Disturbances often act quickly, like hurricanes, and often with
724 devastating effects, however they can also occur over long periods of time. A disturbance that
725 occurs as a relatively discrete event in time is referred to as a "pulse" disturbance, while more
726 gradual or cumulative pressures on a system are referred to as "press" disturbance. Both types of
727 disturbances are part of the natural variability of dwarf-flowered heartleaf ecological systems,
728 and must be considered when assessing redundancy. While there is certainly a variety of
729 potential pulse disturbances for the species (timber harvest, hydrological alterations, road and
730 right-of-way construction), the primary potential catastrophic disturbances are press disturbances
731 from long term climate change, which have great potential to affect ecosystem processes and
732 communities by altering the underlying abiotic conditions (DeWan et al. 2010).

733

734 As stated previously, there are 78 populations of dwarf-flowered heartleaf that have been
735 observed since 2005 (Table 4.1), and resilience of these populations is as follows: 28 (very high);
736 5 (high); 26 (moderate); 19 (low). The populations are spread across the range, although a
737 majority occur in North Carolina. Although, there appears to be adequate redundancy within the
738 range of dwarf-flowered heartleaf to withstand the impacts of localized press catastrophic
739 disturbances, the species range is very small, making it potentially vulnerable to long-term
740 catastrophic events, such as climate change.

741

742 **CHAPTER 5: INFLUENCES ON VIABILITY**

743

744 *Hexastylis naniflora* populations occur in rapidly growing urban areas with expanding suburbs of
745 Charlotte, NC, to the east; Hickory, NC, to the north; and Greenville and Spartanburg, SC, to the
746 south. At the time of listing, it was determined that the species was most threatened by habitat
747 loss due to the conversion of land to residential, commercial, and industrial use in these areas.
748 In addition to threats associated with residential, commercial, and industrial development, other
749 documented threats include habitat loss from land conversion to agricultural use, timber harvest,
750 hydrological alterations from the damming of ponds, impacts from grazing cattle, ORV damage,
751 trampling from foot traffic, invasive species, highway or road improvements, and erosion or

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Caldwell	83,919	86,723	88,689	91,126	92,870
Catawba	157,424	159,799	162,175	164,549	166,447
Cleveland	98,862	99,685	100,004	100,128	100,170
Gaston	221,112	227,667	237,344	245,276	252,388
Iredell	179,740	195,623	211,501	227,383	240,088
Lincoln	84,494	91,034	96,865	103,069	107,858
Polk	21,273	21,823	22,288	22,681	22,955
Rutherford	67,880	68,154	68,283	68,341	68,368



Table 5.2- Human population projections for South Carolina counties within the range of dwarf-flowered heartleaf. Source: U.S. Census Bureau, 2000 Census and 2007 Population Estimates. Population projections calculated by South Carolina Budget and Control Board, Office of Research and Statistics.

County	2020	2025	2030	2035
Cherokee	61,760	64,760	67,350	70,170

back to 113 → I thought it was at 78

809 SCNDR 2010). Another 16 populations have been specifically reported to be threatened by one or more of these same sources. Therefore, threats have either occurred or are reasonably

810 foreseeable within 42 of the 113 populations (corresponding to 37% of all known populations).

811 Of these 42 populations, all or portions of 22 (50%) had been adversely impacted by activities

812 requiring ESA Section 7 consultation with the USFWS. The fact that nearly 20% of all known

813 populations had been subject to formal Section 7 consultation illustrates the threats faced by the

814 species.

815 In the same 2010 review, the most recurrent source of habitat destruction, and certainly the most common trigger for Section 7 consultations involving *H. naniflora* is road and bridge

816 improvement projects. Ten of the 27 largest populations (containing more than 1,000 rosettes)

817 have been the subject of Section 7 consultations between the USFWS and the NCDOT.

818 Collectively, these projects have adversely impacted or are currently expected to impact some

819 22,135 rosettes. In most cases the Section 7 process has resulted in avoidance or minimization of

820 adverse effects through relocation of plants and/or commitments of on-site protection to those

821 plants remaining (post-construction) within NCDOT right-of-way (ROW).

822 Other forms of economic development have also resulted in the destruction or modification of habitats occupied by *H. naniflora*; in many cases, these activities have also required Section 7

823 consultations with the USFWS. Examples of these activities include the maintenance or

824 expansion of hydroelectric and drinking water reservoirs, construction of an industrial

825 development complex, and maintenance activities (in compliance with Federal Aviation

826 Administration standards) at a regional airport. Collectively, these activities have involved the

827 loss or relocation of several thousand rosettes.

828 Blalock Reservoir in Spartanburg County, South Carolina was once estimated to contain the

829 largest population of *H. naniflora*, with over 11,000 rosettes reported here in 1997 (JL&G, 1998).

830 This population was the subject of a section 7 consultation as a result of a proposal to raise the

831 elevation of Blalock Reservoir, which provides water supply storage to Spartanburg County and

832 the City of Spartanburg (USFWS, 2001). Approximately one-third of this population was

833 directly threatened by inundation, and the Federal agency committed to the relocation of some

870 populations are secured against habitat conversion, but lack designated managers with the
871 technical expertise and available resources (funding and personnel) to address this threat.

875 *Climate Change*

876
877 There is a growing concern that climate change may lead to increased frequency of severe storms
878 and droughts (McLaughlin *et al.* 2002, p. 6074; Golladay *et al.* 2004, p. 504; Cook *et al.* 2004, p.
879 1015). Because typical habitats for this species include moist soils adjacent to creeks,
880 streamheads, or along lakes and rivers, and plants have been observed to grow larger and have
881 more frequent flowering in floodplains along rivers, lakes, and streams (Newberry 1993),
882 specific effects of climate change to the dwarf-flowered heartleaf are likely related to changes in
883 soil moisture associated with potential increases in drought.

884
885 Warming in the Southeast is expected to be greatest in the summer (NCCV 2016) which is
886 predicted to increase drought frequency, while annual mean precipitation is expected to increase
887 slightly, leading to increased flooding events (IPCC 2013, p.7; NCCV 2016). Changes in
888 climate may affect ecosystem processes and communities by altering the abiotic conditions
889 experienced by biotic assemblages resulting in potential effects on community composition and
890 individual species interactions (DeWan *et al.* 2010, p.7).

891
892 Despite the recognition of potential climate effects on ecosystem processes, there is uncertainty
893 about what the exact climate future for the Southeastern US will be and how the ecosystems and
894 species in this region will respond. Although climate change was not a factor leading to the
895 original listing of the species, it should be recognized that the greatest threat from climate change
896 may come from synergistic effects. That is, factors associated with a changing climate may act as
897 risk multipliers by increasing the risk and severity of more imminent threats. As a result, impacts
898 from rapid urbanization in the region might be exacerbated under even a mild to moderate
899 climate future.

900

901 Regardless of a pessimistic, optimistic, or status quo climate future, the following systematic changes are expected to be realized to varying degrees in the Southeastern US (IPCC 2013):

- 902
- 903
- 904 • More frequent drought
- 905 • More extreme heat (resulting in increases in air and water temperatures, Figure 5-3)
- 906 • Increased heavy precipitation events (e.g., flooding)
- 907 • More intense storms (e.g., frequency of major hurricanes increases)
- 908 • Rising sea level and accompanying storm surge
- 909

910 In recent years, the Southeast has experienced moderate to severe droughts that many observers have implicated in population declines and poor transplant survivorship (NCNHP, 2010). A

911 wildfire, presumably brought on or at least exacerbated by drought conditions, burned portions

912 of one of the largest known populations in 2009 (Foothills Landfill in Caldwell County; Golder

913 and Associates, 2009). Accelerated climate change is expected to increase the frequency and

914 extent of drought conditions across the southeast (Karl, et al. 2009). The extent to which these

915 climate changes will significantly affect populations of dwarf-flowered heartleaf is currently

916 unknown.

917

918

919 Appendices 4a and 4b gives summary reports on historical and future predicted climate

920 parameters from the USGS National Climate Change Viewer for both North Carolina and South

921 Carolina. As discussed above, the trend for these States is consistent with the general trend in

922 the Southeast: more frequent drought, more extreme heat, and increased precipitation events. If

923 these predictions hold true, dwarf-flowered heartleaf habitat would likely be impacted through

924 increased evaporative rates and decreased soil moisture (Appendices 4a and 4b), increased

925 potential for catastrophic wildfire events, as well as potential disruption of stream bank

926 morphology through increased flooding events. Our habitat model indicates a preferred

927 temperature and precipitation range, indicating that the species would be sensitive to a changing

928 climate.

929

930

931

so how do
they respond to
fire? Fire
can be good for
eliminating
competition +
fertilizing the
soil.

Chapter 6: FUTURE CONDITION

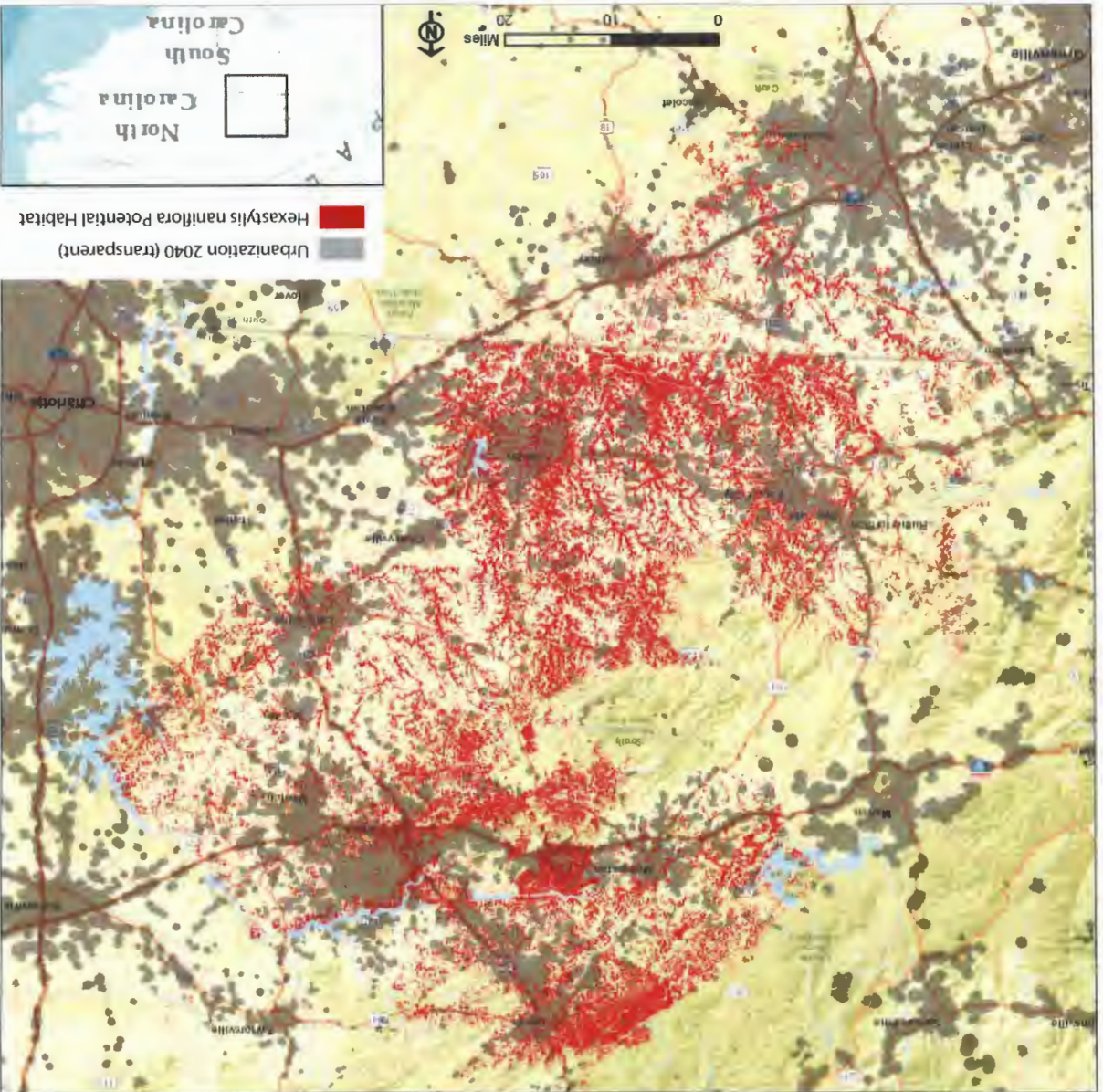
Future Considerations

Our analysis of the past, current, and future influences on what the dwarf-flowered heartleaf needs for long term viability revealed that there are several influences that pose risks to future viability of the species. These risks are primarily related to habitat changes from development and long term climate change. We use projections of urban development to assess potential habitat loss and fragmentation. We also considered how climate change may exacerbate the impacts of development in a qualitative fashion using a narrative approach.

Because the actual impacts of urbanization are unknown, we use three scenarios, projected out to the year 2040, to capture the uncertainty related to the potential impacts to each population's resiliency: Status Quo, Targeted Conservation, and High Development. Results of future projections within each scenario are focused on current populations and potential habitat identified by the Maxent model as described below. Based on the life span of the species, expert input, development as the key risk factor brought forward, uncertainty about future conditions, and lack of knowledge about where additional populations may persist on the landscape, we chose to project populations out to the year 2040 under each scenario, but no further.

In constructing our scenarios, we considered two main influences by which species viability projections could be affected: location of additional populations (positive influence) and habitat loss and fragmentation due to urban development (negative influence). Habitat quantity can be negatively impacted by development or land use change (particularly on private lands) or positively impacted by land acquisition, restoration, and/or introductions into unoccupied sites that already have suitable habitat.

967 We use the Slope, Land cover, Exclusion, Urbanization, Transportation, and Hillshade
968 (SLEUTH) models to determine areas predicted to be urbanized by 2040 (Figure 6.1). SLEUTH
969 is a cellular automata model that applies transition rules to the states of a gridded series of cells,
970 and in this case the transition is that from undeveloped to developed land cover, otherwise
971 known as urbanization, and has been successfully applied worldwide over the last 15 years to
972 simulate land use change (Clarke 1995).
973
974 **Figure 6.1.** Results of the SLEUTH model with *Hexastylis naniflora* potential habitat predicted
975 by the MAXENT model overlaid.
976



The SLEUTH model predictions are broken down by probabilities of urbanization, ranging from 0-100%. We chose 80% probability as our cutoff, as this cutoff has been used by USGS and other SSAs, and this threshold represents a highly likely outlook for urbanization of the landscape. To forecast viability using urban development projections, we assessed the following:

- % increase in projected development (SLEUTH probability of urbanization >80%) within current populations (from Current Conditions—68 populations)

I thought this was 78?

986 • % increase in projected development (SLEUTH probability of urbanization >80%) within
 987 areas delineated as potential habitat by the Maxent habitat model

988
 989 There is no data available on the exact relationships between urbanization and the impacts to
 990 dwarf-flowered heartleaf. We do know that several current populations are located in areas with
 991 surrounding urban landscapes. We also know that urban development has led to extirpation of
 992 populations in the past through loss of habitat. Because of this uncertainty, we attempted to
 993 capture unknowns in two ways. First, our scenarios reflect a range of potential impacts from
 994 urban development. Also, we used two thresholds for % increase in urban development to
 995 capture potential deleterious effects: 25% and 50%. Our assumptions were that very small
 996 increases in development are unlikely to negatively impact populations; development increase of
 997 at least 25% of the area of current populations was likely to have some negative impacts;
 998 development increase of at least 50% was likely to have significant impacts to populations. We
 999 also assume that populations currently on protected lands are likely to see smaller impacts from
 1000 urbanization compared to those that are not protected, but protection status (perpetuity vs non-
 1001 perpetuity) matters. For example, Registered Heritage Areas are non-binding agreements with
 1002 a land owner, and if the land changes ownership, or the owner decides not to continue with the
 1003 agreement, then the Registry is no longer valid. Appendix 4 shows the protection status of each
 1004 delineated population which helped to inform our assessment of resilience under each scenario.

1005
 1006 We also assessed potential positive effects by integrating the potential location or rediscovery of
 1007 additional populations throughout the range into two of our scenarios: Targeted Conservation
 1008 and Status Quo. We believe this is appropriate for several reasons. First, location of new EOs is
 1009 common; many of the populations we consider for Current Conditions include detections that
 1010 have occurred within the last few years. Second, we did not include many older detections (i.e.
 1011 only included detections since 2005), although many of those detections are likely to
 1012 persist. Dwarf-flowered heartleaf is a long-lived perennial, and several EOs have been revisited
 1013 after more than 10 years and the species was present. For example, one such EO was first
 1014 observed in 1957 and next observed in 2001. It seems as long as suitable habitat is still present it
 1015 is reasonable to assume that the species is still there. Finally, there is plenty of predicted suitable

1016 habitat present within older EOs based on the Maxent model predictions that were not included

why not?

1017 as current populations.

1018

1019 The first step in identifying additional areas where dwarf-flowered heartleaf is likely to be found

1020 in the future, was to identify EOs from populations that were last observed prior to 2005 (i.e. our

1021 cut-off for current populations). Although our focus is on older EOs, where dwarf-flowered

1022 heartleaf is likely to persist into the future, we also included current EOs (2005-current) in our

1023 analysis because we were interested in how the older EOs compared to those known to be

1024 persisting on the landscape since 2005. Also, by including older EOs that are within current

1025 delineated populations, we can investigate whether current populations might be predicted to

1026 contain more plants than the most recent abundance estimate. For example, many of our current

1027 populations consist of multiple EOs, and we only considered EOs that were detected from 2005-

1028 current. If these older EOs within current populations that were not included in our Current

1029 Condition assessment are found to be likely to persist, then it is possible we underestimated the

1030 resilience of that population.

1031

1032 Once these older EOs were identified, we created a 1,000 meter buffer around the population and

1033 calculated a number of useful metrics including resilience category based on the last known

1034 abundance estimate, Maxent habitat model metrics, and the results of the SLEUTH model to

1035 further refine a list of potential sites where the species would likely be found to persist within our

1036 20-25 year projection window. Resilience categories were assessed using last known abundance

1037 in the same way as populations assessed in the Current Conditions section (i.e. low = less than

1038 100 individuals; moderate = 100-500 individuals; high = 500-1000 individuals; very high =

1039 greater than 1,000 individuals). We assessed two habitat metrics for these older EOs: average

1040 Maxent score and % Maxent classified as 0.8-1.0 score. Average Maxent score was calculated

1041 by taking the mean Maxent score of all potential habitat within the 1,000 foot buffer. The %

1042 Maxent classified as 0.8-1.0 represents the percentage of all potential habitat within the 1,000

1043 foot buffer that falls within the highest habitat class. Together, these two habitat metrics give

1044 general estimates of habitat quantity and quality. Finally, we calculated the total percentage of

1045 the 1,000 foot buffer around each EO that is projected to be urbanized in the year 2040, which

1046 helps capture the primary risk factor of development when assessing the areas where dwarf-

and what does the Maxent score actually tell us? that is not explained

only the buffer? not the EO itself?
I don't know what "highest" means here
most suitable? as

1047 flowered heartleaf is likely to persist. Table 6.1 (North Carolina) and 6.2 (South Carolina) show all of the EOs we considered and the corresponding metrics associated with resilience categories, urban development, and habitat scores.

1051 **Table 6.1.** North Carolina raw data for metrics assessed to investigate potential sites where dwarf-flowered heartleaf was historically found and is likely to persist. Resilience categories are based on last known abundance estimates as follows: 1 = low; 2 = moderate; 3 = high; 4 = very high. MAXENT Average Mean refers to the mean Maxent score of all potential habitat. % Maxent classified as 0.8-1.0 represents the percentage of all potential habitat that falls within the highest habitat class. % Urban Development refers to the percentage of the 1,000 foot buffer around the EO that is projected to be urbanized in the year 2040.

EO not part of a current population
EO included as part of a current population
EO is a part of a current population but last detection was prior to 2005
Eliminated/not scored

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
1	2	34	1	3
2				
3	2	22	0	10
4	2	22	0	7
5	2	21	0	0
6				
8	1	27	0	6
9	3	44	4	0
10	4	33	2	0
11				
12	4	54	10	0
13	1	31	1	30
14	2	61	16	7
15				
16	4	18	0	47
17	1	50	13	0
18	1	36	8	2
19				
20	2	22	1	88
21	2	34	4	54
23	4	15	0	8
25	1	47	15	30
27				

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
28	2	43	12	29
29	4	43	8	30
30	4	27	2	74
31	4	30	3	86
32	2	34	2	47
33	2	33	3	0
34	1	49	13	63
35	1	42	10	23
36	1	19	0	12
37	4	41	6	17
38	2	14	0	46
39	1	19	0	11
40	2	37	2	32
44	4	20	0	59
45	1	27	5	13
46	3	42	6	6
47	1	28	1	96
48	1	14	0	12
49	4	61	14	5
50				
51	4	52	11	18
52	2	46	4	0
53	1	35	4	24
54	1	35	1	10
55	4	30	0	0
56	2	40	2	6
57	2	21	0	80
58	1	42	5	0
59	2	11	0	49
60	1	25	0	2
61	3	41	0	0
62	2	34	0	0
63	1	27	0	6
64	2	39	9	11
69	2	46	11	19
70	2	38	1	0
71	2	30	2	0
72	2	52	14	0
73	4	60	17	1

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
74	3	65	14	4
75	4	47	6	9
76	4	42	4	10
77	3	31	1	27
79	2	39	1	0
80	1	43	4	15
83	2	17	0	11
84	2	13	0	1
85	2	42	4	5
87				
89	2	13	2	0
90	2	28	2	0
91	1	49	5	0
92	2	15	0	30
106	4	39	4	38
107	1	14	0	40
113	4	46	4	7
114				
115	2	37	3	26
118	3	42	0	9
121	2	41	5	0
122	1	12	0	39
124	1	12	0	9
125	4	15	0	41
130	2	17	0	24
149	4	64	17	3
151	2	16	0	27
154	4	30	1	22
157	2	20	0	0
158	3	36	7	5
159	4	62	24	60
160	3	62	24	32
161	4	64	28	30
162	1	32	2	58
163	2	15	0	56
164	3	18	0	52
165	1	13	0	56
166	1	14	0	40
167	4	30	0	20

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
168	4	19	0	34
169	1	30	0	12
170	2	17	0	40
172	1	39	3	7
173	2	30	1	48
174	1	42	4	16
175				
180	2	21	1	0
181	4	29	2	0
182	4	45	4	0
183	2	15	0	5
184	4	19	0	19
187	2	20	1	35
188	2	24	0	53
189	1	25	0	14
190				
191	2	34	2	0
192	2	35	3	0
193	2	36	7	6
194	4	51	14	18
195	1	21	0	96
196	1	23	4	67
197	4	35	8	38
198	2	32	6	25
199	2	29	5	43
200	1	26	2	87
201	1	39	4	63
202	4	35	4	85
203	1	43	4	49
204				
205	2	43	1	49
206	1	37	3	66
207	2	33	2	85
208	1	32	1	67
209	2	33	2	94
210				
212	1	37	3	85
213	1	36	4	72
219	1	32	1	4

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
222	2	23	3	7
223				
224	1	22	3	17
225	2	24	2	12
227	4	55	2	5
229	2	28	0	21
230	1	54	15	13
231	1	41	7	0
233	4	53	12	14
235	2	50	8	6
236	2	62	14	5
237	2	67	16	5
238	4	51	15	0
239	2	63	14	5
240	1	57	18	0
241	2	62	16	3
242	1	53	9	0
246	1	62	13	4
249	4	47	5	0
250	4	45	4	0
251	4	43	4	0
254	2	54	18	6
255				
256	2	54	15	13
258	3	19	0	51
259	4	25	0	0
262	4	29	2	50
263				
264				
265				
266				
267	2	29	1	0
268	1	33	2	0
269	2	49	17	0
270	1	46	18	1
271	1	26	7	0
272	1	33	0	71
273	2	28	2	0
274	2	50	8	0

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
275	2	12	0	0
276	4	42	5	21
277				
278				
279	1	32	4	89
280	2	64	30	30
281	1	64	31	36
282	1	64	31	51
283	1	65	34	59
284	1	64	35	45
286				
287	2	15	0	35
291	2	21	1	84
292	2	14	0	83
293	1	8	0	16
294	2	36	4	61
296	2	3	0	5
297				
298	2	16	0	1
299	1	12	0	0
300	1	9	0	18
303	2	31	0	0
304	2	31	0	0
305	1	30	2	0
306	1	4	0	53
308	2	15	0	3
309	1	5	0	0
310	4	58	26	35
311	2	15	0	0
312	4	17	0	57
313				
314				
315	1	36	4	61
317	1	15	0	53
318	2	34	4	52
319	4	43	4	10
320	4	41	6	98
321				

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	Min	
				Max	Min
				1	4
				3	67
				0	35
				0	98
				% Urban Development	

Table 6.2. South Carolina raw data for metrics assessed to investigate potential sites where dwarf-flowered heartleaf was historically found and is likely to persist. Resilience categories are based on last known abundance estimates as follows: 1 = low; 2 = moderate; 3 = high; 4 = very high. MAXENT Average Mean refers to the mean Maxent score of all potential habitat. % Maxent classified as 0.8-1.0 represents the percentage of all potential habitat that falls within the highest habitat class. % Urban Development refers to the percentage of the 1,000 foot buffer around the EO that is projected to be urbanized in the year 2040.

EO not part of a current population
EO included as part of a current population
EO is a part of a current population but last detection was prior to 2005
Eliminated/not scored

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
1	2	21	0	0
2	2	1	0	4
3				
4	1	13	0	10
5	2	0	0	64
6	1	0	0	36
7	4	27	0	35
8	2	0	0	14
9				
10				
11	4	14	0	52
12				
13	1	7	0	100
14	4	14	0	43
15	1	0	0	4
16	4	22	0	38
17	4	22	0	33
18	3	19	0	52
19	1	12	0	65
20	2	5	0	100
21	3	5	0	90
22	1	0	0	0
23				

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
24	1	4	0	3
25	1	14	0	48
26	4	12	0	65
27	4	18	1	40
28	4	19	1	49
29				
30	2	7	0	88
31	4	0	0	0
32	2	7	0	93
33	2	2	0	20
34	1	31	3	1
35	1	23	1	53
36	2	6	0	0
37	1	24	2	0
38	4	5	0	37
39	1	6	0	1
40	2	6	0	20
41	1	11	0	87
42	2	3	0	6
43	1	23	0	43
44				
45				
46	1	10	0	96
47				
48				
49	3	8	0	70
50	2	5	0	54
51	1	0	0	35
52	3	0	0	0
53	2	10	0	66
54	2	9	0	91
55	1	4	0	99
56	2	14	0	96
57	3	15	0	38
59	2	4	0	17
60	4	17	1	12

Min	1	0	0	0
Max	4	31	3	100

EO_Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
---------	---------------------	----------------------	--------------------------------	---------------------

1069 Next, we implemented a set of ranking rules using the data from Tables 6.1 and 6.2 to further
 1070 assess which EOs had a higher likelihood of persistence on the landscape. We used SMART
 1071 methodology to quantify and implement our ranking rules. Because the metrics of interest vary
 1072 in data type (i.e. categorical vs continuous) and range of values (i.e. not all continuous variables
 1073 have the same maximum and minimum), our first step was to normalize all of the data on a scale
 1074 of 0-100. Normalization techniques allow for aggregation of criteria with numerical and
 1075 comparable data. We decided to analyze North and South Carolina data separately because the
 1076 Maxent model predicts habitat differently across state lines due to differences in soil
 1077 classification. We weighted each variable according to our opinion of the level of contribution
 1078 each variable had to the probability of persistence of that particular EO. This resulted in
 1079 abundance having the highest weight (100%), with habitat (as calculated by average Maxent
 1080 score) and urbanization given relatively similar weighting (80%). The results of the
 1081 normalization procedure and weighting can be found in Tables 6.3 and 6.4.

1082
 1083 **Table 6.3.** Normalized scores for SMART analysis of North Carolina EOs and weighting scores.
 1084 Resilience category represents the normalized scoring based on the last known abundance
 1085 (0=low; 33=moderate; 67=high; 100=very high); MAXENT Mean is the normalized score of the
 1086 average Maxent rank of all potential habitat; MAXENT percent 0.8-1 represents the normalized
 1087 score of the percentage of potential habitat that falls within the highest rank category; 80% or
 1088 greater SLEUTH Percent of Total is the total amount of current urbanization plus predicted
 1089 urbanization at year 2040 (>80% probability) from the SLEUTH model.

EO not part of a current population	EO included as part of a current population	EO is a part of a current population but last detection was prior to 2005	Eliminated/not scored
-------------------------------------	---	---	-----------------------

EO_Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
1	33	49	3	97
2				
3	33	30	0	90
4	33	29	0	93
5	33	28	1	100
6				

So this isn't projected rather
 is there a current? *cod. line?*
 different than the 1-4 previous categories from tables 6.1 + 6.2?

Can this be defined here?

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
8	0	37	0	94
9	67	65	11	100
10	100	46	6	100
11				
12	100	80	28	100
13	0	43	2	69
14	33	90	44	93
15				
16	100	23	0	52
17	0	73	37	100
18	0	52	22	98
19				
20	33	30	3	11
21	33	48	12	45
23	100	19	0	92
25	0	68	42	69
27				
28	33	62	33	71
29	100	63	22	69
30	100	38	5	24
31	100	43	8	12
32	33	48	5	52
33	33	47	8	100
34	0	73	37	35
35	0	60	29	77
36	0	25	0	88
37	100	60	17	82
38	33	17	0	53
39	0	24	0	89
40	33	54	7	67
44	100	26	1	40
45	0	37	14	86
46	67	60	18	94
47	0	39	2	2
48	0	17	0	88
49	100	91	39	95
50				
51	100	77	31	82
52	33	68	11	100

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
53	0	50	11	76
54	0	49	1	90
55	100	43	0	100
56	33	58	7	94
57	33	28	0	19
58	0	60	15	100
59	33	12	0	50
60	0	34	1	98
61	67	59	1	100
62	33	49	0	100
63	0	38	0	94
64	33	56	24	88
69	33	67	31	80
70	33	55	3	100
71	33	42	5	100
72	33	77	41	100
73	100	89	48	99
74	67	97	41	95
75	100	69	16	91
76	100	61	11	89
77	67	43	2	72
79	33	56	4	100
80	0	62	11	85
83	33	22	0	89
84	33	15	0	99
85	33	61	10	95
87				
89	33	15	5	100
90	33	38	5	100
91	0	71	13	100
92	33	18	0	70
106	100	56	10	61
107	0	16	0	59
113	100	68	11	93
114				
115	33	53	8	74
118	67	61	1	91
121	33	59	13	100
122	0	14	0	60

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
124	0	13	0	91
125	100	19	0	58
130	33	22	0	76
149	100	95	49	97
151	33	20	0	72
154	100	41	2	78
157	33	26	0	100
158	67	51	20	95
159	100	92	69	39
160	67	92	69	68
161	100	95	79	69
162	0	45	7	41
163	33	18	0	43
164	67	24	0	47
165	0	16	0	43
166	0	16	0	59
167	100	41	0	79
168	100	25	0	65
169	0	42	0	88
170	33	22	0	60
172	0	56	8	93
173	33	42	3	52
174	0	62	12	84
175				
180	33	28	2	100
181	100	41	6	100
182	100	66	12	100
183	33	18	1	95
184	100	24	0	81
187	33	27	2	64
188	33	33	0	46
189	0	33	1	86
190				
191	33	48	7	100
192	33	49	10	100
193	33	51	19	94
194	100	75	40	81
195	0	28	0	3
196	0	30	10	32

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
197	100	50	24	61
198	33	45	18	74
199	33	41	14	56
200	0	35	6	11
201	0	56	11	36
202	100	49	11	13
203	0	62	11	50
204				
205	33	62	4	50
206	0	52	8	33
207	33	47	4	14
208	0	45	4	32
209	33	46	5	4
210				
212	0	53	9	14
213	0	52	11	27
219	0	45	2	96
222	33	31	9	92
223				
224	0	29	8	83
225	33	32	6	88
227	100	81	7	95
229	33	39	0	79
230	0	80	44	87
231	0	59	20	100
233	100	79	34	86
235	33	74	22	94
236	33	93	41	95
237	33	100	46	95
238	100	74	41	100
239	33	94	40	94
240	0	85	51	100
241	33	93	47	97
242	0	78	27	100
246	0	93	38	95
249	100	68	13	100
250	100	65	12	100
251	100	62	11	100
254	33	80	51	93

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
255				
256	33	80	44	87
258	67	25	0	48
259	100	34	0	100
262	100	41	6	49
263				
264				
265				
266				
267	33	41	3	100
268	0	46	7	100
269	33	72	49	100
270	0	67	52	99
271	0	35	19	100
272	0	47	0	28
273	33	39	7	100
274	33	73	23	100
275	33	14	0	100
276	100	61	14	79
277				
278				
279	0	46	11	9
280	33	95	85	70
281	0	95	88	64
282	0	96	88	48
283	0	97	95	40
284	0	95	100	54
286				
287	33	18	0	64
291	33	28	4	14
292	33	16	0	16
293	0	7	0	84
294	33	52	11	38
296	33	0	0	95
297				
298	33	20	0	99
299	0	13	0	100
300	0	9	0	82
303	33	44	1	100

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
304	33	43	0	100
305	0	42	5	100
306	0	1	0	46
308	33	18	0	97
309	0	3	0	100
310	100	86	75	64
311	33	19	0	100
312	100	22	0	42
313				
314				
315	0	51	10	38
317	0	19	0	46
318	33	48	12	47
319	100	63	12	89
320	100	60	17	0
321				

Weights			
100	60	20	80

Table 6.4. Normalized scores for SMART analysis of South Carolina EOs and weighting scores. Resilience category represents the normalized scoring based on the last known abundance (0=low; 33=moderate; 67=high; 100=very high); MAXENT Mean is the normalized score of the average Maxent rank of all potential habitat; MAXENT percent 0.8-1 represents the normalized score of the percentage of potential habitat that falls within the highest rank category; 80% or greater SLEUTH Percent of Total is the total amount of current urbanization plus predicted urbanization at year 2040 (>80% probability) from the SLEUTH model.

EO not part of a current population
EO included as part of a current population
EO is a part of a current population but last detection was prior to 2005
Eliminated/not scored

EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
1	33	67	14	100
2	33	2	0	96
3				
4	0	42	3	90
5	33	0	0	36

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EO Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
6	0	0	0	64
7	100	87	2	65
8	33	0	0	86
9				
10				
11	100	43	0	48
12				
13	0	23	0	0
14	100	43	0	57
15	0	0	0	96
16	100	72	1	62
17	100	70	1	67
18	67	62	0	48
19	0	37	0	35
20	33	16	0	0
21	67	15	0	10
22	0	1	0	100
23				
24	0	13	0	97
25	0	44	0	52
26	100	40	0	35
27	100	56	18	60
28	100	60	28	51
29				
30	33	22	0	12
31	100	0	0	100
32	33	23	0	7
33	33	5	0	80
34	0	100	100	99
35	0	75	34	47
36	33	18	0	100
37	0	78	66	100
38	100	16	0	63
39	0	19	0	99
40	33	18	0	80
41	0	36	0	13
42	33	10	0	94
43	0	72	0	57
44				

EO_Code	Resilience Category	Average Maxent Score	% Maxent classified as 0.8-1.0	% Urban Development
45				
46	0	32	0	4
47				
48				
49	67	27	0	30
50	33	16	0	46
51	0	1	0	65
52	67	0	0	100
53	33	33	0	34
54	33	29	0	9
55	0	13	0	1
56	33	43	0	4
57	67	47	8	62
59	33	13	0	83
60	100	53	21	88

Weights			
100	60	20	80

1102

1103 To determine a final rank for likelihood of persistence, we calculated a weighted sum for each
 1104 EO. We then converted the weighted sum to a final rank value that ranged from 0-100. Finally,
 1105 we determined the top 10% or 90th percentile, and top 25% or 75th percentile ranking for EOs in
 1106 each state. Table 6.5 summarizes the final ranks and top 10% and 25% percentile ranks for
 1107 North and South Carolina. We will include the top 10% in the status quo scenario, and the top
 1108 25% in the conservation scenario.

1109

1110 **Table 6.5.** Final Rank Scores for EOs in North and South Carolina. Dark green represents the
 1111 top 10% of scores, and light green includes the top 25% of scores.

EO not part of a current population

EO included as part of a current population

EO is a part of a current population but last detection was prior to 2005

Eliminated/not scored

1112

South Carolina

EO_Code	Final Score
60	79
7	79
17	75

North Carolina

EO_Code	Final Score
149	94
73	93
49	92

I don't know what this table is supposed to be telling me.

You lost me with too much stats. Less detail, more explanation of purpose for normalizing and using percentiles

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16	74
27	71
28	70
31	69
14	66
11	63
38	62
34	61
1	60
26	59
52	56
57	56
18	55
37	54
36	48
42	44
2	43
40	42
59	41
49	41
8	39
33	39
4	37
39	35
35	34
43	34
24	33
21	32
22	31
53	31
50	31
15	30
25	26
56	24
5	24
54	22
30	22
32	20
51	20
6	20
19	19

12	236
238	90
161	88
227	87
249	86
233	86
182	85
250	85
251	84
194	84
51	84
310	84
75	84
113	84
319	81
76	81
74	81
10	80
181	79
55	79
37	79
276	78
259	77
159	77
29	76
160	73
167	72
9	72
154	72
23	71
106	71
197	71
61	70
46	70
184	69
237	69
158	68
118	68
241	68
239	67
236	66

28	51
242	51
17	51
5	50
180	50
270	50
157	50
222	49
230	49
115	48
281	48
91	48
4	48
298	48
311	48
225	48
198	47
89	47
3	47
84	47
308	47
275	47
183	46
40	46
284	46
258	46
231	46
229	46
58	46
164	46
83	45
282	44
18	44
205	43
172	42
296	42
283	42
268	42
80	41
130	41
174	41

265	0
266	0
277	0
278	0
286	0
297	0
313	0
314	0
321	0

Below we describe how we integrated potential positive and negative influences across the scenarios. We can assume there is some tipping point at which an area becomes so urbanized it is unsuitable for dwarf-flowered heartleaf, but we don't know exactly what that tipping point is. Similarly, we can assume additional populations are likely to be found or rediscovered across the range, but there is no clear way to predict the exact number or location of these populations. Although there is great uncertainty associated with how the species will be influenced by these factors, the three scenarios are intended to capture the range of this uncertainty. Note, changes in climate have potential to exacerbate the effects of urbanization, but these effects are not likely to occur within our projection window (e.g. 2040).

Status Quo Scenario

Under the status quo scenario, we assume a few populations will be identified as persisting throughout the range, and that there will be a range of impacts from urbanization that are related to the % increase in urban development and whether a population is protected or not. We assessed population resilience under the following assumptions:

- Two additional populations are identified as persisting based on Maxent model metrics, last known abundance category, and total predicted urbanization from SLEUTH modelling. Six additional EOs within currently delineated populations not included in our Current Conditions analysis are predicted to persist based on the same metrics.
- Potential impacts of urban development based on SLEUTH Model projections focused on current delineated populations:
 - Protected areas

Just because we have in the past, doesn't mean we will continue to find more. That's a big assumption and makes a big difference. For the sure about this?

in addition to what #?

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High Development Scenario

Under the high development scenario, we assume no additional populations will be identified as persisting throughout the range, and that impacts from urbanization that are relatively high, and are also affected by whether a population is protected or not. We assessed population resilience under the following assumptions:

- No additional populations are identified as persisting
- Potential impacts of urban development based on SLEUTH Model projections focused on current delineated populations:

- Protected areas

- Protected in perpetuity—population drops 1 resilience rank if % increase in urbanization exceeds >50% threshold
- Voluntary protection/non-perpetuity—population drops 1 resilience rank if % increase in urbanization exceeds >25% threshold; population drops 2

resilience ranks if % increase in urbanization exceeds >50% threshold

- Non-protected—population drops 1 resilience rank if % increase in urbanization exceeds >25% threshold; population drops 2 resilience ranks if % increase in

urbanization exceeds >50% threshold; extirpation of populations if % increase in urbanization exceeds >90% threshold.

Targeted Conservation Scenario

Under the targeted conservation scenario, we assume it is likely several additional populations (i.e. more than status quo scenario) will be identified as persisting throughout the range. The

- Protected in perpetuity—no negative impacts from urbanization
- Voluntary protection/non-perpetuity—population drops 1 resilience rank if % increase in urbanization exceeds >50% threshold
- Non-protected—population drops 1 resilience rank if % increase in urbanization exceeds >25% threshold; population drops 2 resilience ranks if % increase in urbanization

Why just 1 resilience rank?

resilience

rank?

~~that~~

are also affected by whether a population is protected or not. We assessed population resilience

under the following assumptions:

- No additional populations are identified as persisting
- Potential impacts of urban development based on SLEUTH Model projections focused on

current delineated populations:

- Protected areas

- Protected in perpetuity—population drops 1 resilience rank if % increase in urbanization exceeds >50% threshold
- Voluntary protection/non-perpetuity—population drops 1 resilience rank if % increase in urbanization exceeds >25% threshold; population drops 2

resilience ranks if % increase in urbanization exceeds >50% threshold

- Non-protected—population drops 1 resilience rank if % increase in urbanization exceeds >25% threshold; population drops 2 resilience ranks if % increase in

urbanization exceeds >50% threshold; extirpation of populations if % increase in urbanization exceeds >90% threshold.

Targeted Conservation Scenario

Under the targeted conservation scenario, we assume it is likely several additional populations (i.e. more than status quo scenario) will be identified as persisting throughout the range. The

Why this high? Do we really believe anything would persist at higher than 80-75% development?

1166 range of impacts from urbanization are the same as the Status Quo scenario. We assessed

1167 population resilience under the following assumptions:

- 1168 • Six populations are identified as persisting based on Maxent model metrics, last known

1169 abundance category, and total predicted urbanization from SLEUTH modelling. Six

1170 additional EOs within currently delineated populations not included in our Current

1171 Conditions analysis are predicted to persist based on the same metrics.

- 1172 • Potential impacts of urban development based on SLEUTH Model projections focused on

1173 current delineated populations:

- 1174 ○ Protected areas

- 1175 ▪ Protected in perpetuity—no impacts from urbanization

- 1176 ▪ Voluntary protection/non-perpetuity—population drops 1 resilience rank if

1177 % increase in urbanization exceeds >50% threshold

- 1178 ○ Non-protected—population drops 1 resilience rank if % increase in urbanization

1179 exceeds >25% threshold; population drops 2 resilience ranks if % increase in

1180 urbanization exceeds >50% threshold

1182 Future Resilience

1184 Our focus on future resilience of dwarf-flowered heartleaf is on the potential impacts from

1185 urbanization. Table 6.6 shows a summary of currently delineated populations and the predicted

1186 urban development to occur within each of the populations. The table only includes those

1187 populations that already have some current amount of urban development, or are predicted to

1188 have some amount of development occur by the year 2040. Populations not included in this

1189 table are not predicted to be urbanized at all, so for the purposes of future analysis, will be

1190 assumed to retain the same resilience category as current. For those populations included in the

1191 table, we focus on those populations that are anticipated to increase in urbanization beyond a

1192 threshold value, depending on the scenario, but thresholds include >25% and >50% increases:

1193 Also taken into account is whether or not a population is on protected lands, and if so, whether

1194 the population is protected in perpetuity or not. Below is a summary of projected future

1195 resilience under each of the three scenarios.

what
about 95%
identified
as the last
page?

1231 very high (27); high (6); moderate (23); low (17); and 2 additional populations identified as
 1232 persisting, with an unknown resilience. Six EOs within currently delineated populations not
 1233 included in our Current Conditions analysis are predicted to persist, but resilience is unchanged
 1234 because each of the populations are already predicted to be of very high resilience. When
 1235 comparing future population resilience to current condition a few populations drop in their
 1236 resilience category. One current population of very high resilience is predicted to drop to high
 1237 resilience; two moderate populations are predicted to drop to low resilience; and five populations
 1238 (one currently moderate and four currently low) are predicted to be extirpated due to urban
 1239 development. Of the seven additional populations predicted to persist under this scenario, four
 1240 are in South Carolina, and three in North Carolina. We did not assess resilience for these
 1241 additional populations, but it is worth mentioning that the last time these populations were
 1242 detected, resilience was very high (2), high (1), and moderate (4).

Table 6.7. Predicted resilience categories for *Hexastylis naniflora* populations under the Status Quo scenario, and comparison to current condition.

Site Name	Current Resilience	Status Quo
DNR Peters Creek Heritage Preserve	very high	very high
Cowpens NBF	very high	very high
Mill Creek Forest and Seep	very high	very high
Island Creek Heath Bluff	very high	very high
NCDOT TIP: R-2824	very high	very high
Murrays Mill/Uppper Balls Creek NA	very high	very high
Big Horse Creek Rare Plant Site	very high	very high
Broad River/Sandy Run NA	very high	very high
New Hope Springhead Swamp	very high	very high
Facebook Site	very high	very high
Davenport Road/Mountain View Rare Plant Site	very high	very high
Broad River: Floyds Creek	very high	very high
Catawba River: Hoyle Ck-Micol Ck	very high	very high
South Fork Catawba R: Clark Ck, Miller Br, Cata Mem Hos	very high	very high
Buffalo Creek: Tributaries N and S of SR 2047	very high	high
Buffalo Creek: Kings Mountain Res	very high	very high
Broad River: Brushy Creek	very high	very high
Peaked Top Rare Plant Site/Foothills Landfill	very high	very high
Jacob Fork West Corridor	very high	very high
Floyds Creek Tributary Rare Plant Site	very high	very high

Disclaimer: THIS INFORMATION IS DISTRIBUTED SOLELY FOR THE PURPOSE OF PRE-DISSEMINATION PEER REVIEW UNDER APPLICABLE INFORMATION QUALITY GUIDELINES. IT HAS NOT BEEN FORMALLY DISSEMINATED BY THE USFWS. IT DOES NOT REPRESENT AND SHOULD NOT BE CONSTRUED TO REPRESENT ANY AGENCY DETERMINATION OR POLICY.

Site Name	Current Resilience	Status Quo
New Bethel Rare Plant Site	very high	very high
Leepers Creek Heartleaf Site	very high	very high
Cliffside Steam Station	very high	very high
Rhyme Conservation Preserve	very high	very high
Glade Creek, Alex County	very high	very high
Richardson Creek trib above Toms Lake	very high	very high
Gunpowder Creek: South of Hudson	very high	very high
Taylor Blaylock Res	very high	very high
Little Gunpowder Creek Rare Plant Site 1	high	high
Little Gunpowder Creek Rare Plant Site 2	high	high
Buffalo Creek Rare Plant Site	high	high
Northern Catawba County	high	high
Rock Barn Solar Farm	high	high
NCDOT TIP R-2824	moderate	moderate
Third Creek Rare Plant Site	moderate	moderate
Knob Creek NA	moderate	moderate
Buffalo Creek: Northeast of SR 1903	moderate	moderate
West Shelby Mesic Slope	moderate	low
Cat Square Heartleaf Forest	moderate	low
Kross Keys NA	moderate	moderate
First Broad River: Crooked Run Creek	moderate	moderate
NCDOT non-TIP Div 12 road const at SR 1115	moderate	moderate
South Fork Catawba River Jacobs Fork and Camp Creek	moderate	moderate
Catawba River: North Fork Mountain Creek	moderate	moderate
Catawba River: Lake James	moderate	moderate
Hogpen Branch Transplant Site	moderate	moderate
Jonas Road Rare Plant Site	moderate	extirpated
South Fork Catawba River, Henry Fork	moderate	moderate
No Business Creek, Boyd Tract	moderate	moderate
Broad River/Sandy Run NA	moderate	moderate
Buffalo Shoals Creek	moderate	moderate
Fox Knoll Farm	moderate	moderate
Forest City: Adj to Isothermal CC	moderate	moderate
Hickory Area	moderate	moderate
UT of Kings Mountain Res	moderate	moderate
Brushy Creek Headwaters	moderate	moderate
Smith Cliff/Henry Fork River	moderate	moderate
Simms Hill/Little River Uplands	moderate	moderate
Collinsville (Hughes) Creek Slopes	moderate	moderate

Site Name	Current Resilience	Status Quo
Burke County - Drowning Creek UT	moderate	moderate
Sandy Spring Church Springhead Swamp	low	low
First Broad River: Hickory Creek	low	low
Buffalo Creek: Ravine	low	extirpated
Buffalo Creek: Potts Creek	low	extirpated
Smith Cliff/Henry Fork River	low	low
Pott Creek	low	low
Northeast Lincoln: UT Walker Branch	low	extirpated
Gunpowder Creek	low	low
Killian Crossroads	low	low
Beaverdam Crk at First Broad River	low	low
Lincoln County, SR-1314	low	low
Levan Family Farm	low	low
Fanjoy Road Site	low	extirpated
First Broad River: Beaverdam Creek Tribs	low	low
South Mountains Pleasant Grove Uplands	low	low
NCDOT TIP R-3603A	low	low
Hickory Creek - UT (Shelby High School)	low	low
Boulder Creek Subdivision	low	low
Gateway Elementary School	low	low
First Broad River (North Carolina)	n/a	present
Cherokee Creek/Bonner and Robin School Roads	n/a	present

High Development Scenario

In the High Development scenario, there are predicted to be 72 populations of dwarf-flowered heartleaf on the landscape (Table 6.8). The predicted resilience of the extant populations are as follows: very high (27); high (4); moderate (25); and low (16). No new future populations are predicted to be discovered. When comparing future population resilience to current condition a few populations drop in their resilience category. One current population of very high resilience is predicted to drop to moderate resilience; one high resilience population is predicted to drop to moderate; two moderate populations are predicted to drop to low resilience; and six populations (one currently moderate and five currently low) are predicted to be extirpated due to urban development.

Table 6.8. Predicted resilience categories for *Hexastylis naniflora* populations under the High Development scenario, and comparison to current condition.

Site Name	Current Resilience	High Development
DNR Peters Creek Heritage Preserve	very high	very high
Cowpens NBF	very high	very high
Mill Creek Forest and Seep	very high	very high
Island Creek Heath Bluff	very high	very high
NCDOT TIP: R-2824	very high	very high
Murrays Mill/Upper Balls Creek NA	very high	very high
Big Horse Creek Rare Plant Site	very high	very high
Broad River/Sandy Run NA	very high	very high
New Hope Springhead Swamp	very high	very high
Facebook Site	very high	very high
Davenport Road/Mountain View Rare Plant Site	very high	very high
Broad River: Floyds Creek	very high	very high
Catawba River: Hoyle Crk-Micol Crk	very high	very high
South Fork Catawba R: Clark Crk, Miller Br, Cata Mem Hos	very high	very high
Buffalo Creek: Tributaries N and S of SR 2047	very high	moderate
Buffalo Creek: Kings Mountain Res	very high	very high
Broad River: Brushy Creek	very high	very high
Peaked Top Rare Plant Site/Foothills Landfill	very high	very high
Jacob Fork West Corridor	very high	very high
Floyds Creek Tributary Rare Plant Site	very high	very high
New Bethel Rare Plant Site	very high	very high
Leepers Creek Heartleaf Site	very high	very high
Cliffside Steam Station	very high	very high
Rhyme Conservation Preserve	very high	very high
Glade Creek, Alex County	very high	very high
Richardson Creek trib above Toms Lake	very high	very high
Gunpowder Creek: South of Hudson	very high	very high
Taylor Blaylock Res	very high	very high
Little Gunpowder Creek Rare Plant Site 1	high	high
Little Gunpowder Creek Rare Plant Site 2	high	high
Buffalo Creek Rare Plant Site	high	high
Northern Catawba County	high	moderate
Rock Barn Solar Farm	high	high
NCDOT TIP R-2824	moderate	moderate
Third Creek Rare Plant Site	moderate	moderate
Knob Creek NA	moderate	moderate
Buffalo Creek: Northeast of SR 1903	moderate	moderate
West Shelby Mesic Slope	moderate	low
Cat Square Heartleaf Forest	moderate	low

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1214	Table 6.6. Results of the SLEUTH model. Populations consist of both stand-alone EOs and
1215	aggregates of multiple EOs following the definition of delineating demographic populations
1216	from Chapter 4. Included are only those populations that already have some current amount of
1217	urban development, or are predicted to have some amount of development occur by the year
1218	2040. Red cells indicate populations that are predicted to increase >50% in urbanization.
1219	Orange cells indicate populations that are predicted to increase >25% in urbanization.
1220	

Population Number	Total Area (sq m)	Already classed Urban	80% chance	90% chance	95% chance	97.5% chance	100% chance	>80%
206	17346.37096	0.40%	0.00%	0.00%	0.00%	6.24%	93.41%	99.63%
306	7804.656249	0.00%	0.00%	0.00%	0.00%	0.00%	22.40%	95.24%
208	55360.86786	17.31%	0.00%	0.00%	0.00%	0.00%	82.69%	82.69%
279	19551.661571	0.00%	0.00%	0.00%	0.00%	0.00%	80.85%	80.85%
214	15043.2984	0.00%	0.00%	1.44%	10.97%	0.00%	55.72%	68.13%
248	25486.15611	28.80%	0.00%	3.22%	0.02%	53.03%	0.02%	56.30%
316	43177.79587	20.06%	0.00%	16.68%	7.08%	20.67%	0.00%	44.43%
247	49898.17159	5.87%	0.00%	6.37%	0.00%	23.35%	0.00%	29.73%
291	11666.76374	35.39%	12.28%	13.53%	2.43%	0.00%	0.23%	28.47%
287	7901.775408	0.00%	0.00%	11.50%	0.00%	0.00%	14.25%	25.75%
312	6535.273235	0.00%	25.28%	0.00%	0.00%	0.00%	0.00%	25.28%
32	31220.60253	60.74%	0.00%	20.39%	0.00%	0.00%	0.00%	20.39%
177	26954.54153	25.34%	12.19%	0.92%	0.10%	5.31%	0.13%	18.66%
292	15611.18205	0.00%	0.00%	0.00%	0.00%	0.00%	18.40%	18.40%
261	21644.22924	0.00%	0.00%	13.21%	3.35%	0.00%	0.00%	16.56%
295	23486.00987	18.20%	0.00%	3.41%	11.99%	0.25%	0.00%	15.65%
125	20742.3249	0.00%	1.02%	5.65%	6.67%	0.00%	0.00%	13.34%
59	8172.007769	0.00%	13.09%	0.00%	0.00%	0.00%	0.00%	13.09%
302	120342.0641	1.46%	2.55%	2.55%	0.77%	2.33%	3.98%	12.19%
178	376781.2214	28.59%	2.79%	2.40%	0.68%	0.59%	2.64%	9.11%
93	43754.11642	0.19%	0.00%	0.00%	0.00%	0.00%	7.82%	7.82%
77	6044.427562	0.00%	1.51%	6.14%	0.00%	0.00%	0.00%	7.64%
179	15145.19453	85.06%	1.14%	0.00%	5.12%	0.00%	0.49%	6.75%
44	15081.76951	61.17%	0.27%	0.00%	0.00%	0.00%	4.68%	4.95%
252	39595.93143	63.47%	0.00%	3.80%	0.00%	0.00%	0.00%	3.80%
100	423621.7376	9.01%	1.32%	1.10%	0.72%	0.14%	0.00%	3.27%
276	123688.7819	0.61%	0.36%	1.87%	0.01%	0.00%	0.00%	2.24%
216	66424.06073	0.00%	0.91%	0.00%	0.00%	0.00%	0.00%	0.91%
154	33924.92259	0.00%	0.00%	0.37%	0.00%	0.00%	0.00%	0.37%
29	249998.8742	0.00%	0.00%	0.05%	0.00%	0.00%	0.00%	0.05%
29	30711.68144	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	36339.91976	11.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	24498.03483	24.77%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
31	42929.76479	100.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
96	95947.32128	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
130	1168.240433	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
176	39787.48373	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
195	7805.599588	99.94%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
317	584.7346337	99.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
318	5396.859208	99.74%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
320	125.5182447	98.79%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Status Quo Scenario

1221 1222 1223 1224 1225 1226 1227 1228 1229 1230
 In the Status Quo scenario, there are predicted to be 75 populations of dwarf-flowered heartleaf on the landscape (Table 6.7). The predicted resilience of the extant populations are as follows:

Site Name	Current Resilience	High Development
Kross Keys NA	moderate	moderate
First Broad River: Crooked Run Creek	moderate	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork	moderate	moderate
Catawba River Jacobs Fork and Camp Creek	moderate	moderate
Catawba River: North Fork Mountain Creek	moderate	moderate
Catawba River: Lake James	moderate	moderate
Hogpen Branch Transplant Site	moderate	moderate
Jonas Road Rare Plant Site	moderate	extirpated
South Fork Catawba River, Henry Fork	moderate	moderate
No Business Creek, Boyd Tract	moderate	moderate
Broad River/Sandy Run NA	moderate	moderate
Buffalo Shoals Creek	moderate	moderate
Fox Knoll Farm	moderate	moderate
Forest City: Adj to Isothermal CC	moderate	moderate
Hickory Area	moderate	moderate
UT of Kings Mountain Res	moderate	moderate
Brushy Creek Headwaters	moderate	moderate
Smith Cliff/Henry Fork River	moderate	moderate
Sims Hill/Little River Uplands	moderate	moderate
Collinsville (Hughes) Creek Slopes	moderate	moderate
Burke County - Drowning Creek UT	moderate	moderate
Sandy Spring Church Springhead Swamp	low	low
First Broad River: Hickory Creek	low	low
Buffalo Creek: Ravine	low	extirpated
Buffalo Creek: Potts Creek	low	extirpated
Smith Cliff/Henry Fork River	low	low
Pott Creek	low	low
Northeast Lincolnton: UT Walker Branch	low	extirpated
Gunpowder Creek	low	extirpated
Killian Crossroads	low	low
Beaverdam Crk at First Broad River	low	low
Lincoln County, SR-1314	low	low
Levan Family Farm	low	low
Fanjoy Road Site	low	extirpated
First Broad River: Beaverdam Creek Tribs	low	low
South Mountains Pleasant Grove Uplands	low	low
NCDOT TIP R-3603A	low	low
Hickory Creek - UT (Shelby High School)	low	low
Boulder Creek Subdivision	low	low

Site Name	Current Resilience	High Development
Gateway Elementary School	low	low

Targeted Conservation Scenario

In the Targeted Conservation scenario, there are predicted to be 79 populations of dwarf-flowered heartleaf on the landscape (Table 6.9). The predicted resilience of the extant populations are as follows: very high (27); high (6); moderate (23); low (17); and 6 additional populations discovered to persist, with an unknown resilience. Six EOs within currently delineated populations not included in our Current Conditions analysis are predicted to persist, but resilience is unchanged because each of the populations are already predicted to be of very high resilience. When comparing future population resilience to current condition a few populations drop in their resilience category. One current population of very high resilience is predicted to drop to high resilience; two moderate populations are predicted to drop to low resilience; and five populations (one currently moderate and four currently low) are predicted to be extirpated due to urban development. Of the sixteen additional populations predicted to persist under this scenario, ten are in South Carolina, and six in North Carolina. We did not assess resilience for these additional populations, but it is worth mentioning that the last time these populations were detected, resilience was very high (2), high (1), moderate (11), and low (2).

Table 6.9. Predicted resilience categories for *Hexastylis naniflora* populations under the Targeted Conservation scenario, and comparison to current condition.

Site Name	Current Resilience	Targeted Conservation
DNR Peters Creek Heritage Preserve	very high	very high
Cowpens NBF	very high	very high
Mill Creek Forest and Seep	very high	very high
Island Creek Heath Bluff	very high	very high
NCDOT TIP: R-2824	very high	very high
Murrays Mill/Upper Balls Creek NA	very high	very high
Big Horse Creek Rare Plant Site	very high	very high
Broad River/Sandy Run NA	very high	very high
New Hope Springhead Swamp	very high	very high
Facebook Site	very high	very high
Davenport Road/Mountain View Rare Plant Site	very high	very high

Site Name	Current Resilience	Targeted Conservation
Broad River: Floyds Creek	very high	very high
Catawba River: Hoyle Crk-Micol Crk	very high	very high
South Fork Catawba R: Clark Crk, Miller Br, Cata Mem Hos	very high	very high
Buffalo Creek: Tributaries N and S of SR 2047	very high	high
Buffalo Creek: Kings Mountain Res	very high	very high
Broad River: Brushy Creek	very high	very high
Peaked Top Rare Plant Site/Foothills Landfill	very high	very high
Jacob Fork West Corridor	very high	very high
Floyds Creek Tributary Rare Plant Site	very high	very high
New Bethel Rare Plant Site	very high	very high
Leepers Creek Heartleaf Site	very high	very high
Cliffside Steam Station	very high	very high
Rhyme Conservation Preserve	very high	very high
Glade Creek, Alex County	very high	very high
Richardson Creek trib above Toms Lake	very high	very high
Gunpowder Creek: South of Hudson	very high	very high
Taylor Blaylock Res	very high	very high
Little Gunpowder Creek Rare Plant Site 1	high	high
Little Gunpowder Creek Rare Plant Site 2	high	high
Buffalo Creek Rare Plant Site	high	high
Northern Catawba County	high	high
Rock Barn Solar Farm	high	high
NCDOT TIP R-2824	moderate	moderate
Third Creek Rare Plant Site	moderate	moderate
Knob Creek NA	moderate	moderate
Buffalo Creek: Northeast of SR 1903	moderate	moderate
West Shelby Mesic Slope	moderate	low
Cat Square Heartleaf Forest	moderate	low
Kross Keys NA	moderate	moderate
First Broad River: Crooked Run Creek	moderate	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork	moderate	moderate
Catawba River Jacobs Fork and Camp Creek	moderate	moderate
Catawba River: North Fork Mountain Creek	moderate	moderate
Catawba River: Lake James	moderate	moderate
Hogpen Branch Transplant Site	moderate	moderate
Jonas Road Rare Plant Site	moderate	extirpated
South Fork Catawba River, Henry Fork	moderate	moderate
No Business Creek, Boyd Tract	moderate	moderate
Broad River/Sandy Run NA	moderate	moderate

Site Name	Current Resilience	Targeted Conservation
Buffalo Shoals Creek	moderate	moderate
Fox Knoll Farm	moderate	moderate
Forest City: Adj to Isothermal CC	moderate	moderate
Hickory Area	moderate	moderate
UT of Kings Mountain Res	moderate	moderate
Brushy Creek Headwaters	moderate	moderate
Smith Cliff/Henry Fork River	moderate	moderate
Simms Hill/Little River Uplands	moderate	moderate
Collinsville (Hughes) Creek Slopes	moderate	moderate
Burke County - Drowning Creek UT	moderate	moderate
Sandy Spring Church Springhead Swamp	low	low
First Broad River: Hickory Creek	low	low
Buffalo Creek: Ravine	low	extirpated
Buffalo Creek: Potts Creek	low	extirpated
Smith Cliff/Henry Fork River	low	low
Pott Creek	low	low
Northeast Lincoln: UT Walker Branch	low	extirpated
Gunpowder Creek	low	low
Killian Crossroads	low	low
Beaverdam Crk at First Broad River	low	low
Lincoln County, SR-1314	low	low
Levan Family Farm	low	low
Fanjoy Road Site	low	extirpated
First Broad River: Beaverdam Creek Tribs	low	low
South Mountains Pleasant Grove Uplands	low	low
NCDOT TIP R-3603A	low	low
Hickory Creek - UT (Shelby High School)	low	low
Boulder Creek Subdivision	low	low
Gateway Elementary School	low	low
First Broad River (North Carolina)	n/a	present
First Broad Hop-Hornbeam NA	n/a	present
Big Island Carolina Hemlock Bluff	n/a	present
Cherokee Creek/Bonner and Robin School Roads	n/a	present
Arrowood Branch	n/a	present
Cherokee Creek/SC 11	n/a	present

Viability Summary

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1282

1283 Urban development is predicted to have negative impacts on several of the current populations
 1284 under all of our scenarios. However, this loss of resilience and extirpation of a few populations
 1285 is offset by the fact that several additional populations were found to persist in the Status Quo
 1286 and Targeted Conservation scenarios. In the High Development Scenario, there is a predicted
 1287 loss of 6 populations, with loss of resilience in several additional populations. Regardless of the
 1288 scenario, the majority of the populations expected to persist on the landscape in 2040 are of at
 1289 least moderate resilience.

1290
 1291 Given the relatively high number of populations across each scenario, redundancy remains
 1292 similar to current conditions. That is to say, there appears to be adequate redundancy within the
 1293 range of dwarf-flowered heartleaf to withstand the impacts of localized press catastrophic
 1294 disturbances, however the species range is relatively small, making it potentially vulnerable to
 1295 long-term catastrophic events, such as climate change.

1296
 1297 Given that dwarf-flowered heartleaf has a very limited range, and after consulting with experts,
 1298 we decided delineating representative units was not appropriate for this species. It is worth
 1299 noting that in two of our scenarios (Status Quo and Targeted Conservation), additional
 1300 populations are found to persist in South Carolina, an area where we have relatively few current
 1301 populations. As discussed below, we believe there are opportunities to find additional
 1302 populations based on the amount of predicted unoccupied potential habitat. Although we did not
 1303 delineate representative units, we believe our scenarios do not predict declines in species
 1304 representation.

1305
 1306 **Table 6.10.** Viability summary for *Hexastylis naniflora* under 3 future scenarios (projected to
 1307 year 2040) and compared to Current Condition.

	CURRENT	STATUS Quo	HIGH DEVELOPMENT	TARGETED CONSERVATION
VERY HIGH	28	27	27	27
MODERATE	26	23	25	23
LOW	19	17	16	17

EXTIRPATED	n/a	5	6	5
PERSISTING	n/a	2	0	6
TOTAL	78	75	72	79

Opportunities for Additional Conservation

1311 Although our scenarios focus on areas where dwarf-flowered heartleaf have been found in the
1312 past, the Maxent model identifies a number of areas as high quality potential habitat for the
1313 species that falls outside the immediately known occurrence areas. A few of these areas are
1314 detailed below (Figure 6.2).
1315 1. West of the city of Lenoir, south of Highway 90/Adako Rd., north of Highway 64 within
1316 Caldwell County. This area identifies a large block of potential habitat. This area falls just
1317 outside the administrative boundary of the Pisgah National Forest. The bluffs and tributaries
1318 along the Johns River are identified as the best habitat, but there is also ample habitat identified
1319 along the forested areas of Celia, Husband, Abingdon and Greasy Creeks. The only known
1320 occurrence within this area is associated with Abingdon Creek and is under a conservation
1321 easement.
1322 2. Henry Fork River bluffs and tributaries east of Highway 18 within Burke County. A
1323 historic element occurrence is present by the Burke County line, but the entire area is identified
1324 as good quality potential habitat for the species where forested habitats remain.
1325 3. South West corner of Catawba County west of Highway 321. Several disjointed patches
1326 of high quality potential habitat are identified in this region associated with the river and creek
1327 slopes. Rock Creek, Jacob Fork River, Pott Creek, and their associated tributaries all contain
1328 blocks of potential habitat. A number of element occurrences are identified within this area, but
1329 additional habitat is identified both upstream and downstream of the known occurrences.
1330
1331 4. Clark, Pinch Gut, Maiden, and Allen Creeks, north of the town of Maiden. The slopes
1332 along these creeks all contain quality potential habitat. Known element occurrences are in the
1333 general area, but none are situated within the creeks listed.

1334	5.	First Broad River North of Highway 74, Rutherford County. Two older element
1335		occurrences are located within this area, however, the forested bluffs along the First Broad River
1336		and associated tributaries are identified as good quality potential habitat in many additional
1337		upstream and downstream areas in this system.
1338	6.	Hickory Creek, Sulphur Springs Branch (Little Hickory), Shoal Creek, and tributaries
1339		draining into First Broad River South of the Town of Shelby, north of the South Carolina border.
1340		The town of Shelby has likely disconnected this site from area 5 listed above. Here, slopes along
1341		the creeks and tributaries draining into the First Broad River are identified as potential habitat
1342		more so than the slopes along the First Broad River themselves. There is only a single element
1343		occurrence known upstream along Hickory Creek.
1344	7.	North Pacolet River and Obed Creek, north of where they join. The majority of potential
1345		habitat falls along the slopes of the North Pacolet River. Two older element occurrences (1991
1346		last observation) are found in the tributaries draining into the North Pacolet River, and many
1347		occurrences are found further upstream. The habitat model suggests that additional undiscovered
1348		habitat areas are present.
1349	8.	Pacolet River and Island Creek, north of Peters Creek, downstream of the Pacolet River
1350		dam. This area displays limited amounts of good quality potential habitat. Recent element
1351		occurrences are present in the upper headwaters of Peters and Zekial Creeks (Zekial Creek drains
1352		into Peters Creek) and in areas north of the Pacolet River dam, but none are known along the
1353		areas identified in this immediate area.
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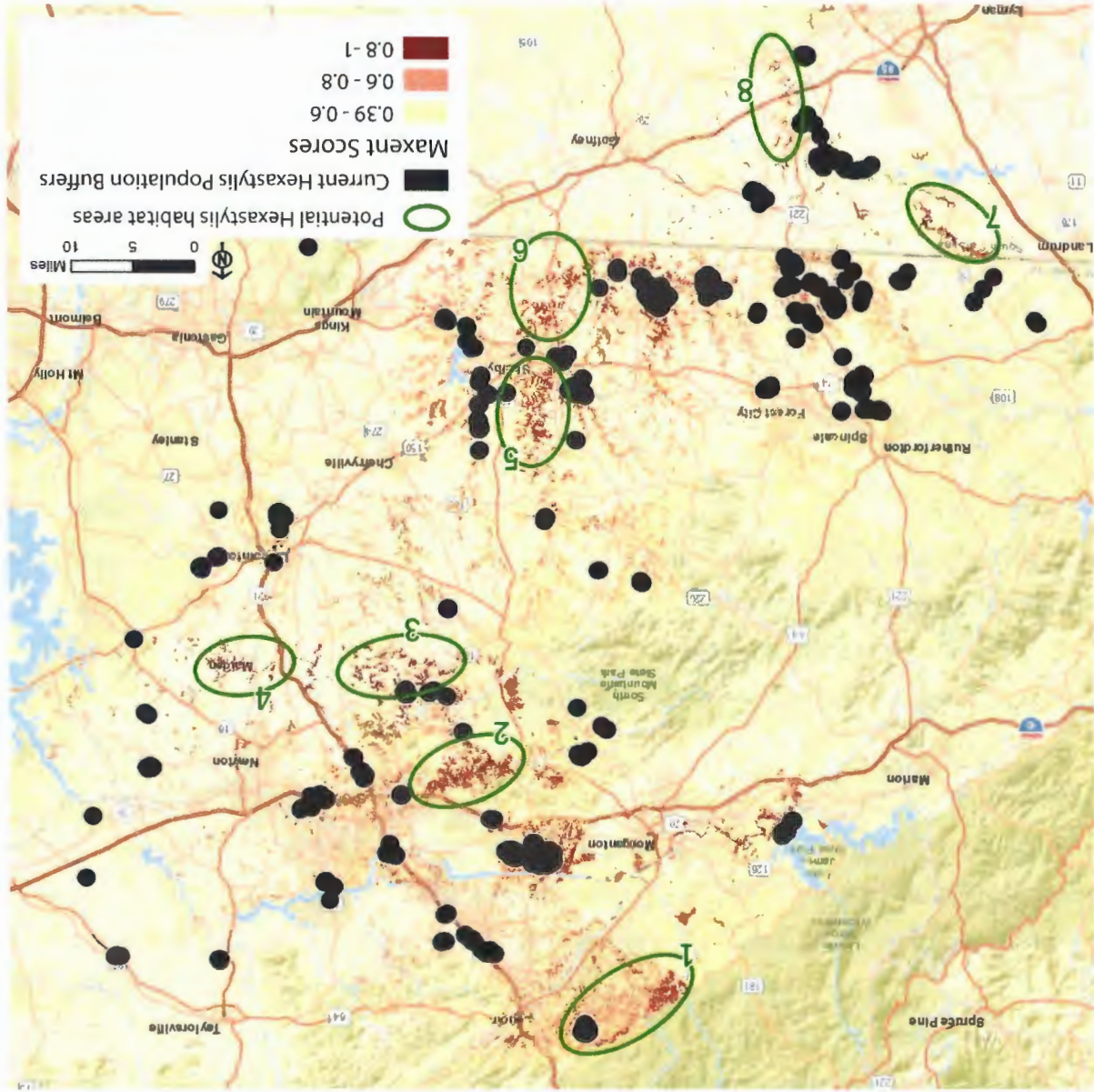


Figure 6.2. Areas identified as high quality potential habitat by Maxent model for *Hexastylis naniflora* that fall outside the immediately known occurrence areas.

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