From:	Marshall, Michael E
To:	Mason, Suzanne; Amoroso, Jame; Matt Estep; tpbassette@ncdot.gov; Endries, Mark; Reid, Rebekah N; Becker, Drew N; Stephanie DeMay
Subject:	HENA Drafts
Date:	Thursday, February 22, 2018 9:19:12 AM
Attachments:	Appendix 1 HENA Range-wide Status Report EO RANK SPECS.pdf Appendix 2 HENA Maxent Model.pdf Appendix 3a NC Climate Projections USGS.pdf Appendix 3b SC Climate Projections USGS.pdf HENA CURRENT CONDITIONS 2.22.18.docx INFLUENCES ON VIABILITY HENA 2.22.18.docx
Importance:	High

Good morning Team!

Sorry for the delay, but here are the next two sections of the HENA SSA attached for your consideration and review, with appendices attached as well. These sections are Current Conditions and Influences on Viability. As you review and provide comments on these sections, we will be working on the Future Conditions section, which will be the final section of the SSA.

Please provide your edits and comments to these documents in track changes by **COB Friday March 2nd.**

Thanks you so much for your help and input on all of this. And, if at any time you have any questions, please feel free to contact me or Rebekah.

Take care and have a great weekend!

Mike

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Mike Marshall
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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

Appendix B3: NC Natural Heritage Program (NCNHP) Element Occurrence Rank Specifications for *Hexastylis naniflora*

"A" Rank Specifications (excellent viability)
An A-ranked population of *Hexastylis naniflora* should have more than 500 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest.

“B” Rank Specifications (good viability)
A B-ranked population of *Hexastylis naniflora* should have 200-500 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - more than 500 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

"C" Rank Specifications (fair viability)
A C-ranked population of *Hexastylis naniflora* should have 100-200 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - 200- 500 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

"D" Rank Specifications (poor viability)
A D-ranked population of *Hexastylis naniflora* should have fewer than 100 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - less than 200 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

“E” Rank Specifications (extant)
An E-ranked population of *Hexastylis naniflora* is an occurrence that has recently been verified as still existing, but sufficient information for the factors used to estimate viability has not yet been obtained.

“H” Rank Specification (historical)
An H-ranked population of *Hexastylis naniflora* lacks recent field information verifying the continued existence of the occurrence. In the absence of known disturbance and with the habitat still extant, H is generally recommended for occurrences that have not been reconfirmed for approximately 30 or more years.

“F” Rank Specification (failed to find)
An F-ranked population of *Hexastylis naniflora* has not been found despite a search by an experienced observer at a time and under conditions appropriate for the Element at a location where it was previously reported, but the occurrence still might be confirmed to exist at that location with additional field survey efforts. For occurrences with vague locational information, the search must include areas of appropriate habitat within the range of locational uncertainty.

“X” Rank Specification (failed to find)
An X-ranked population of *Hexastylis naniflora* is considered destroyed based on adequate surveys by one or more experienced observers at times and under conditions appropriate for the species at the occurrence location, or other persuasive evidence indicates that the species no longer exists there or that the habitat has been destroyed to such an extent that it can no longer support the species.

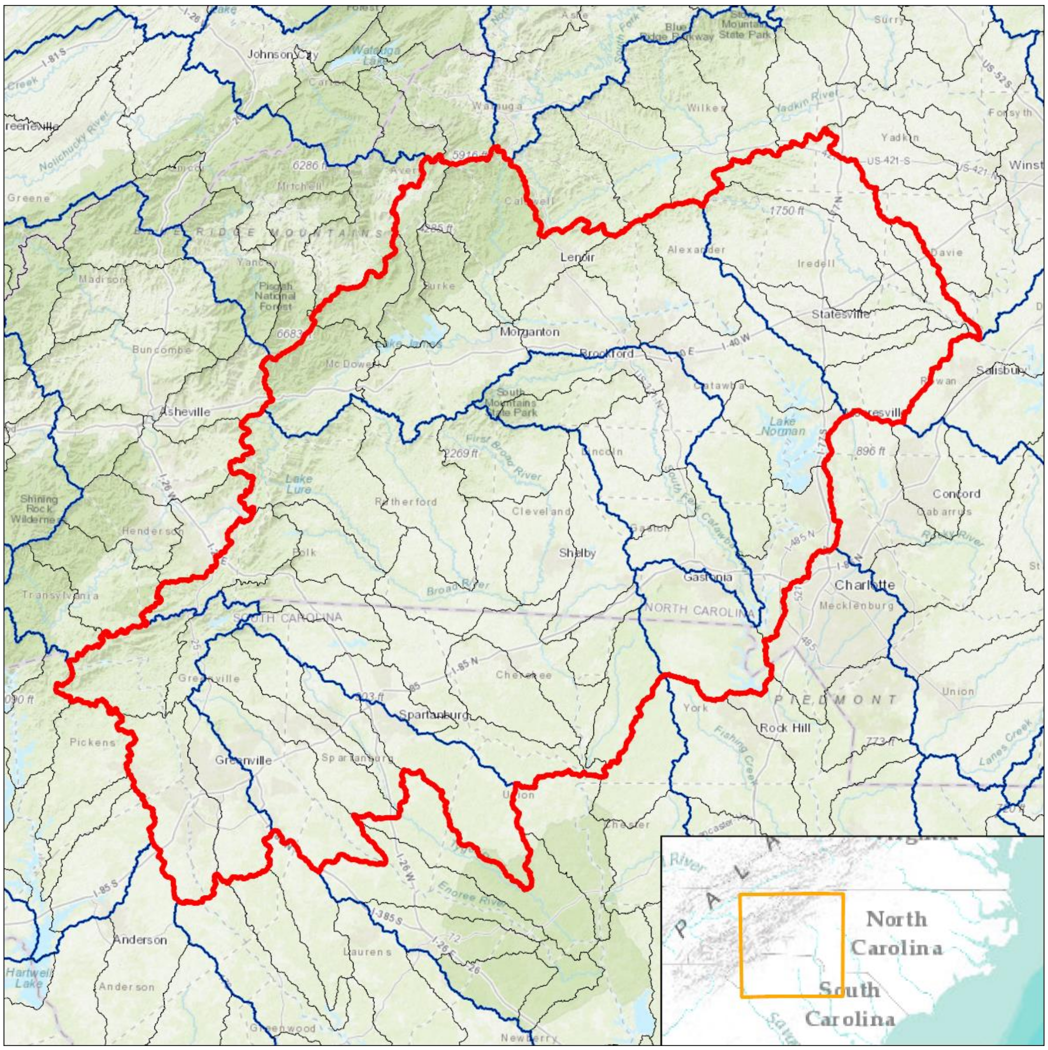
"U" Rank Specification (failed to find)
A U-ranked population of *Hexastylis naniflora* cannot be assigned a rank due to lack of sufficient information on the occurrence or the species identification has not been confirmed.

Rank Specifications Justification
The unit of measurement for population size in this species is "clump" (rosette). EO size (as quantified by number of clumps or rosettes) is the primary rank factor. Condition of habitat (vegetation community and structure) and Landscape context (extent of suitable habitat and physical factors) are also incorporated secondarily. The species thrives most in undisturbed habitat. However, disturbed lands, that have been logged, grazed, mown, or converted to pasture, orchards, or tree plantations have been found to support remnant patches of *Hexastylis naniflora*. The extent to which this species can withstand disturbance is unknown. Populations in disturbed habitat are considered at risk, with relatively poor viability (C or D). Care should be taken when estimating population size, as population estimates have been found to vary widely from the number counted in population censuses. Specifications are based on largest known populations and expert opinion (including James Padgett, Carolyn Wells, Misty Buchanan (formerly Franklin), and Brenda Wichmann).

Appendix 2: Maxent Habitat Modelling for Dwarf-flowered Heartleaf

Analysis Extent:

Figure 1. Analysis extent. 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



Coordinate System: USA Contiguous Albers Equal Area Conic USGS version

Cell Size: 30 x 30 meters derived from the USGS National GAP Landcover

Source Datasets Used:

USGS National GAP Landcover - The GAP National Terrestrial Ecosystems – Ver 3.0 is a 2011 update of the National Gap Analysis Program Land Cover Data – Version 2.2 for the conterminous U.S. The GAP National Terrestrial Ecosystems – Version 3.0 represents a highly thematically detailed land cover map of the U.S at a 30 x 30 meter pixel resolution. The map legend includes types described by NatureServe's Ecological Systems Classification (Comer et al. 2002) as well as land use classes described in the National Land Cover Dataset 2011 (Homer et al. 2015). These data cover the entire continental U.S. and are a continuous data layer. The land cover map identifies 49 different land cover types within the range of Hexastylis Naniflora.

SSURGO Soils - The SSURGO database contains information about soil as collected by the National Cooperative Soil Survey over the course of a century. The information was gathered by walking over the land and observing the soil. Many soil samples were analyzed in laboratories. The maps outline areas called map units. The map units describe soils and other components that have unique properties, interpretations, and productivity. The information was collected at scales ranging from 1:12,000 to 1:63,360.

National Elevation Dataset - The NED is a seamless dataset with the best available raster elevation data of the conterminous United States, Alaska, Hawaii, and territorial islands. The NED is derived from diverse source data that are processed to a common coordinate system and unit of vertical measure. NED data are available nationally (except for Alaska) at resolutions of 1 arc-second (about 30 meters) and 1/3 arc-second (about 10 meters), and in limited areas at 1/9 arc-second (about 3 meters). The 1/3 arc-second database was used for HENA modelling purposes.

PRISM Climate Data - The PRISM Climate Group gathers climate observations from a wide range of monitoring networks, applies sophisticated quality control measures, and develops spatial climate datasets to reveal short- and long-term climate patterns. The resulting datasets incorporate a variety of modeling techniques and are available at multiple spatial/temporal resolutions, covering the period from 1895 to the present.

Model Variables Created:

Landcover – Landcover represented by the default landcover classification (Table 1).

Landcover Hexastylis Grouping – Landcover represented by a grouping of landcover types. For the purposes of discussing Hexastylis naniflora habitat, many of the default landcover classifications are similar and could be grouped together. The definition of each landcover classification was reviewed and categorized using a much broader habitat definition (Table 1).

Table 1. Landcover classification

Default Landcover Classification	Hexastylis Grouping
Southern Piedmont Glade and Barrens	Barren
Southern Ridge and Valley / Cumberland Dry Calcareous Forest	Barren
Undifferentiated Barren Land	Barren
Cultivated Cropland	Disturbed
Deciduous Plantations	Disturbed
Developed, High Intensity	Disturbed
Developed, Low Intensity	Disturbed
Developed, Medium Intensity	Disturbed
Developed, Open Space	Disturbed
Disturbed/Successional - Grass/Forb Regeneration	Disturbed
Disturbed/Successional - Shrub Regeneration	Disturbed
Evergreen Plantation or Managed Pine	Disturbed
Harvested Forest - Grass/Forb Regeneration	Disturbed
Harvested Forest-Shrub Regeneration	Disturbed
Introduced Upland Vegetation - Annual Grassland	Disturbed
Introduced Upland Vegetation - Shrub	Disturbed
Introduced Upland Vegetation - Treed	Disturbed
Pasture/Hay	Disturbed
Quarries, Mines, Gravel Pits and Oil Wells	Disturbed
Ruderal forest	Disturbed
Southern Appalachian Low Mountain Pine Forest	Evergreen
Southern Appalachian Montane Pine Forest and Woodland	Evergreen
Southern and Central Appalachian Cove Forest	Hardwood
Southern and Central Appalachian Oak Forest	Hardwood
Southern and Central Appalachian Oak Forest - Xeric	Hardwood
Southern Piedmont Mesic Forest	Hardwood
Central and Southern Appalachian Montane Oak Forest	High Elevation
Central and Southern Appalachian Northern Hardwood Forest	High Elevation
Central and Southern Appalachian Spruce-Fir Forest	High Elevation
Southern Appalachian Grass and Shrub Bald	High Elevation
Southern Appalachian Grass and Shrub Bald - Shrub Modifier	High Elevation
Appalachian Hemlock-Hardwood Forest	Mixed
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	Mixed
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	Mixed

Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	Mixed
Southern Ridge and Valley Dry Calcareous Forest	Mixed
Southern Ridge and Valley Dry Calcareous Forest - Pine modifier	Mixed
Open Water (Fresh)	Open Water/Wetland
Southern and Central Appalachian Bog and Fen	Open Water/Wetland
Southern Piedmont/Ridge and Valley Upland Depression Swamp	Open Water/Wetland
Southern Appalachian Granitic Dome	Outcrop
Southern Appalachian Montane Cliff	Outcrop
Southern Appalachian Rocky Summit	Outcrop
Southern Piedmont Cliff	Outcrop
Southern Piedmont Granite Flatrock	Outcrop
South-Central Interior Large Floodplain - Forest Modifier	Riparian
South-Central Interior Small Stream and Riparian	Riparian
Southern Piedmont Large Floodplain Forest - Forest Modifier	Riparian
Southern Piedmont Small Floodplain and Riparian Forest	Riparian

Landcover Diversity – Identifies the number of landcover classes (default classification) within a 10-cell radius (300 meters) of an individual pixel.

Landcover Majority – Identifies the dominant landcover class (default classification) within a 10-cell radius (300 meters) of an individual pixel.

SSURGO mukey – SSURGO soils dataset represented by the Map Unit Key (mukey)

SSURGO Drainage Class – SSURGO soils dataset represented by wettest drainage class. Drainage class refers to the frequency and duration of wet periods in conditions similar to those under which the soil formed.

SSURGO Hydrologic Group – SSURGO soils dataset represented by hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

Elevation – National elevation dataset elevation values. This 10-meter dataset was reclassified to 30-meters.

Aspect 9-class – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, Northeast, East, Southeast, South, Southwest, West, and Northwest.

Aspect 5-class – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, East, South, and West.

Slope – The national elevation dataset represented by degree of slope.

Geomorphons – A pattern recognition analysis that converts a digital elevation dataset into 10 common landform elements: flat, peak, ridge, shoulder, spur, slope, pit, valley, footslope, and hollow. The national elevation dataset was used as the source elevation for the analysis.

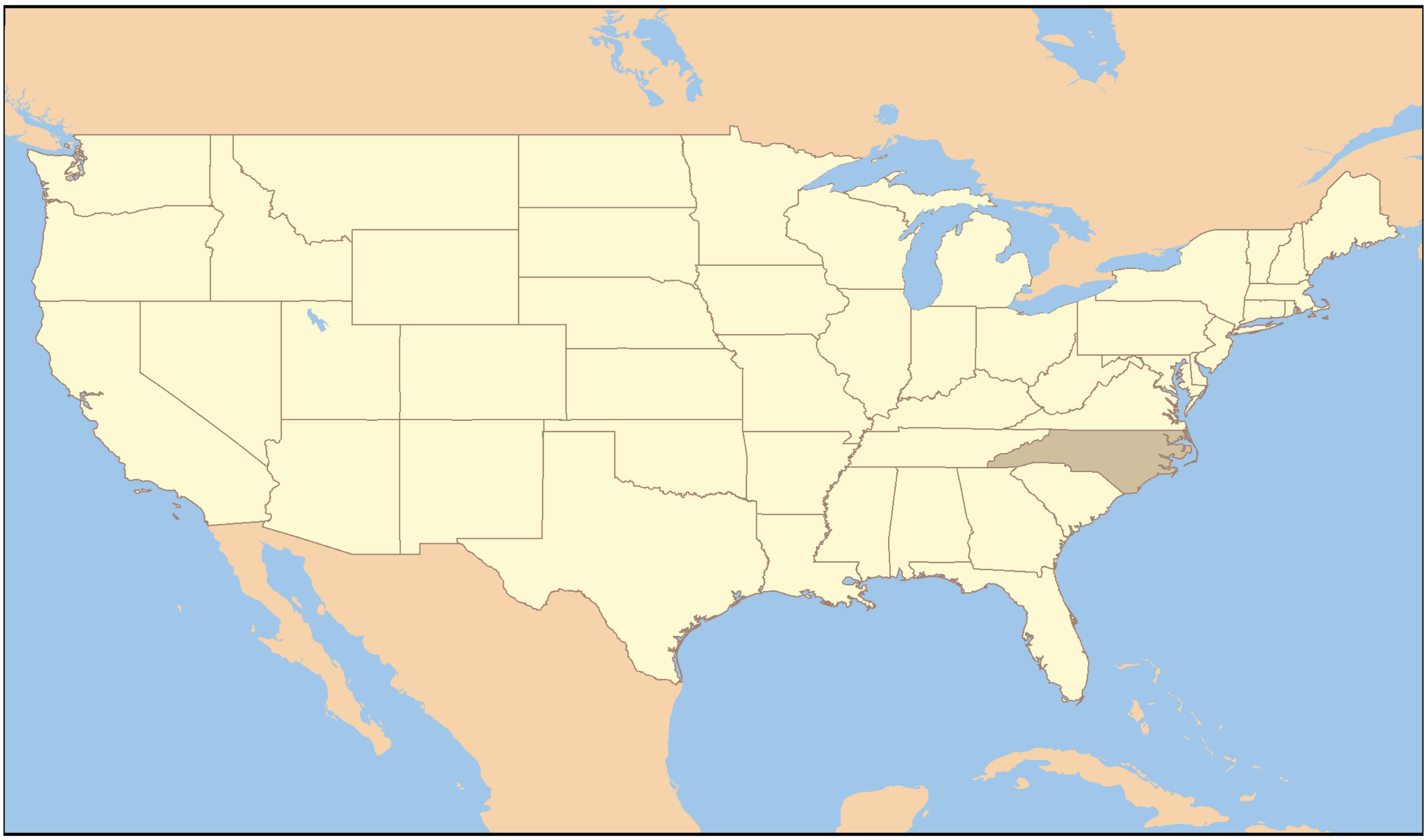
Average Annual Precipitation – Climate dataset of average annual precipitation according to a model using point precipitation and elevation data for the 30-year period of 1971-2000.

Maximum Average Annual Temperature – Climate dataset of average annual maximum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

Minimum Average Annual Temperature – Climate dataset of average annual minimum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

U.S. Geological Survey - National Climate Change Viewer

Summary of North Carolina



December 1, 2016

1 Maximum 2-m Air Temperature

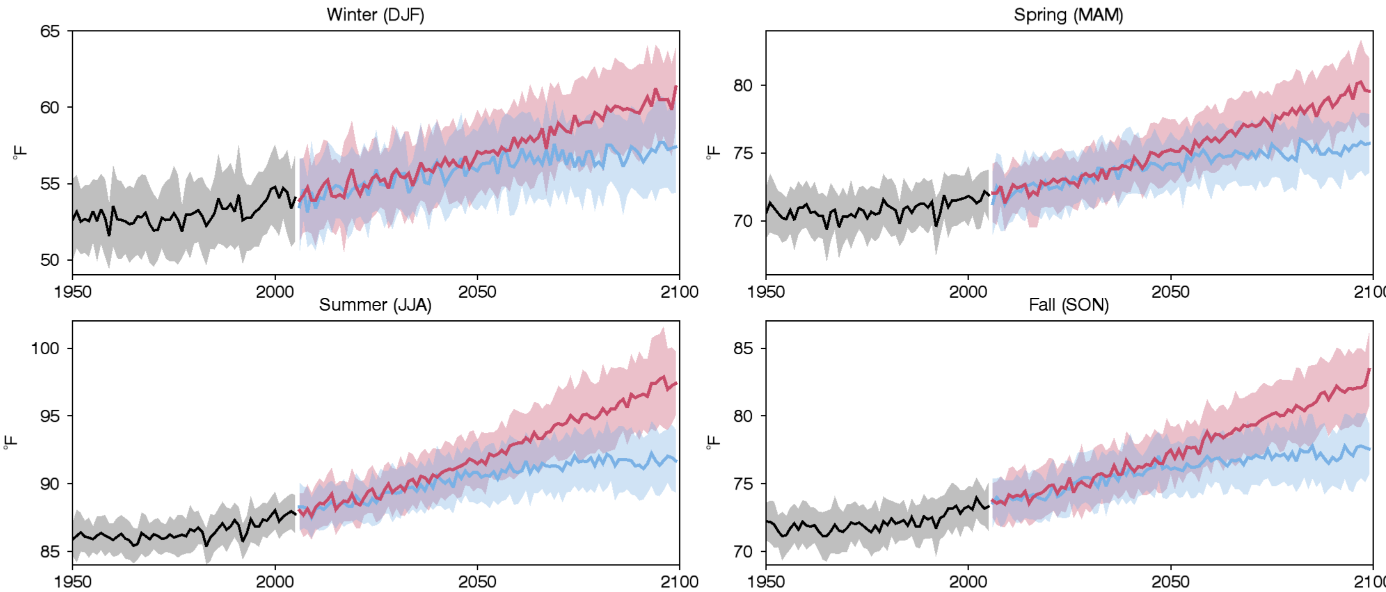


Figure 1: Seasonal average time series of maximum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

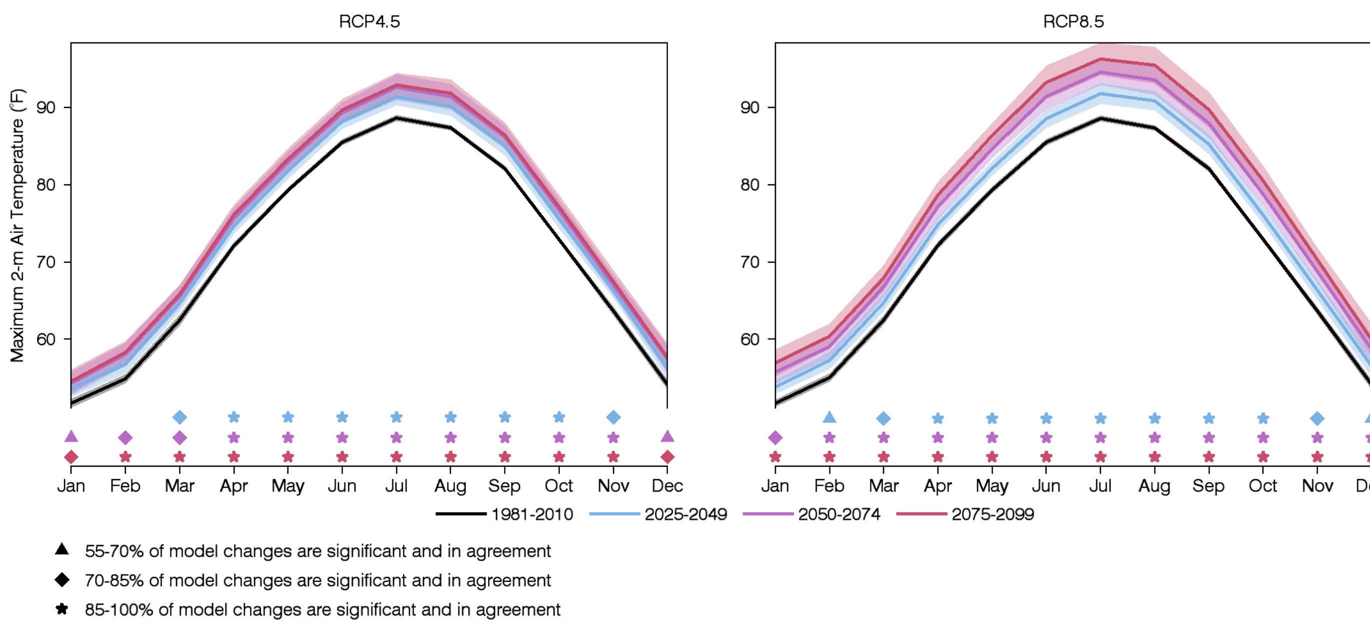


Figure 2: Monthly averages of maximum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

2 Minimum 2-m Air Temperature

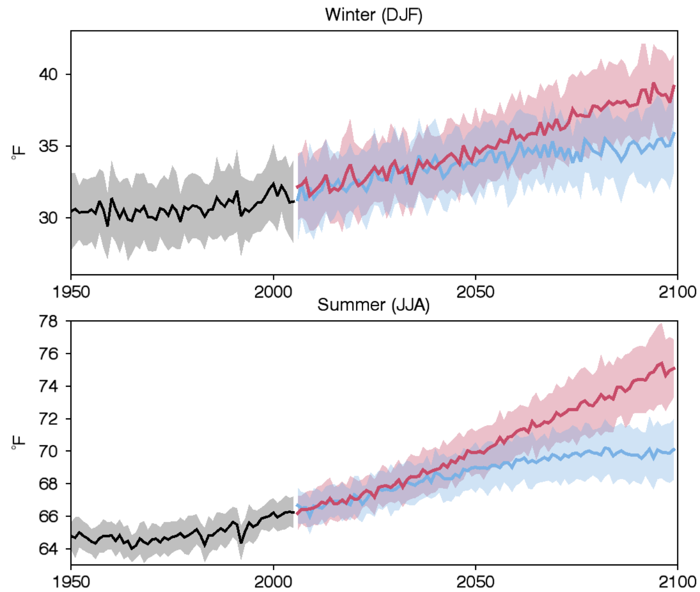


Figure 3: Seasonal average time series of minimum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

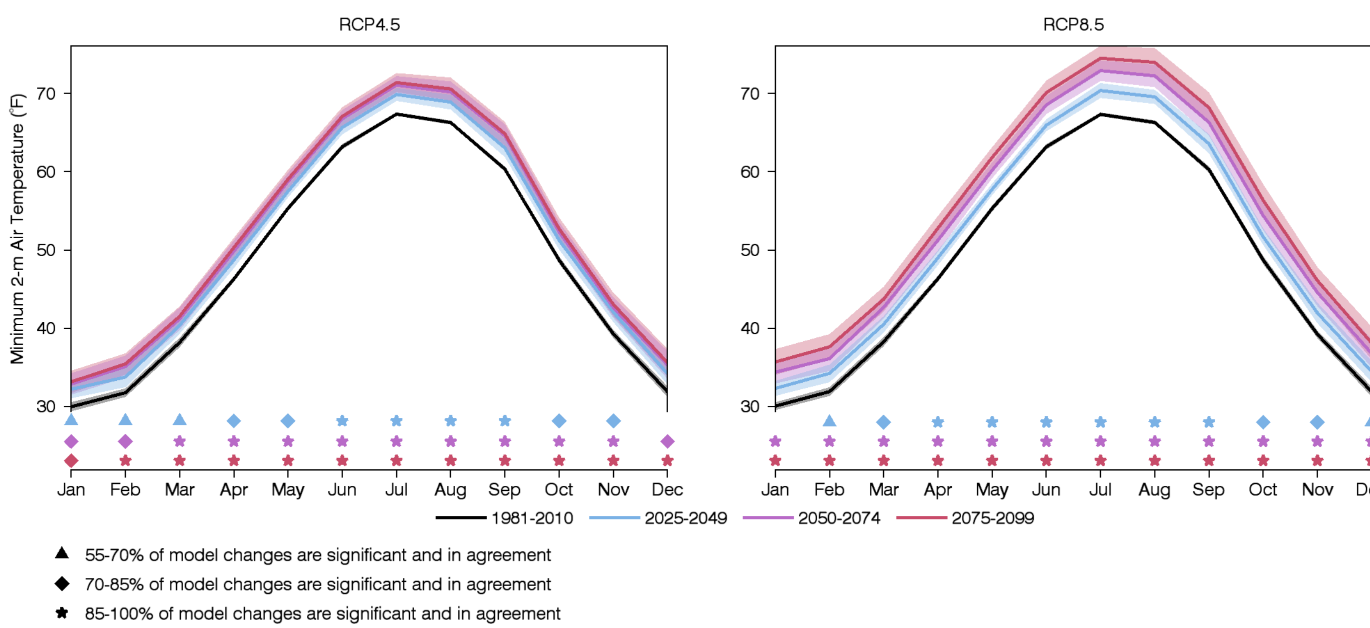


Figure 4: Monthly averages of minimum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

3 Precipitation

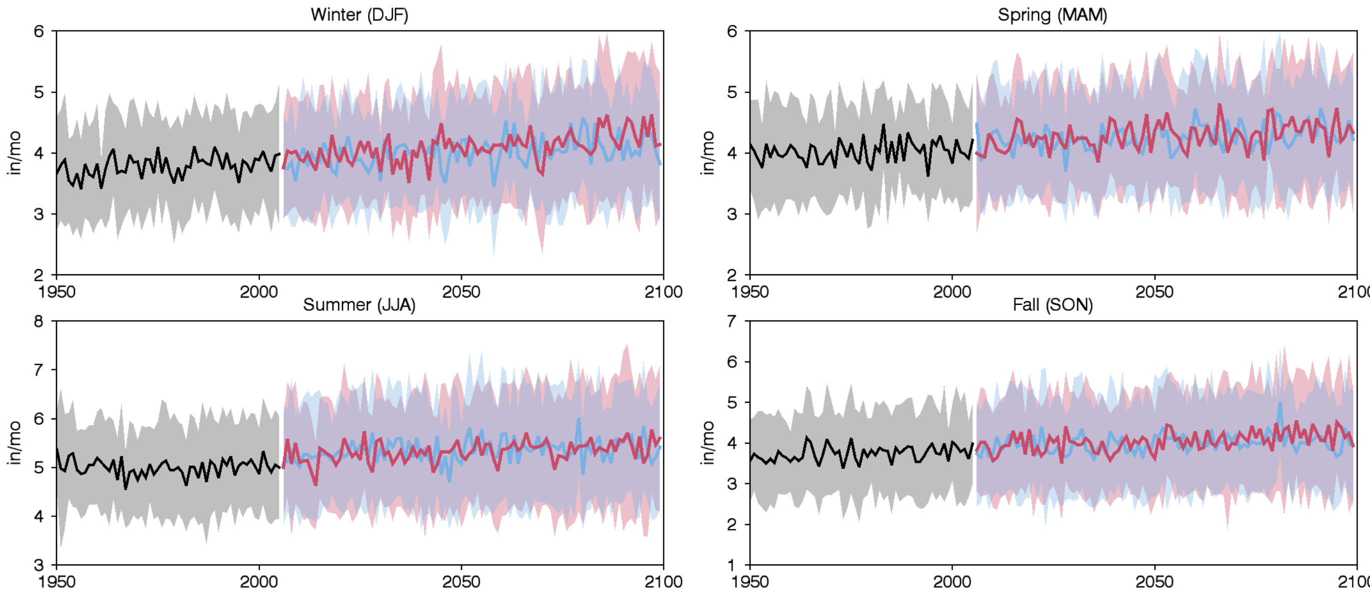


Figure 5: Seasonal average time series of precipitation for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

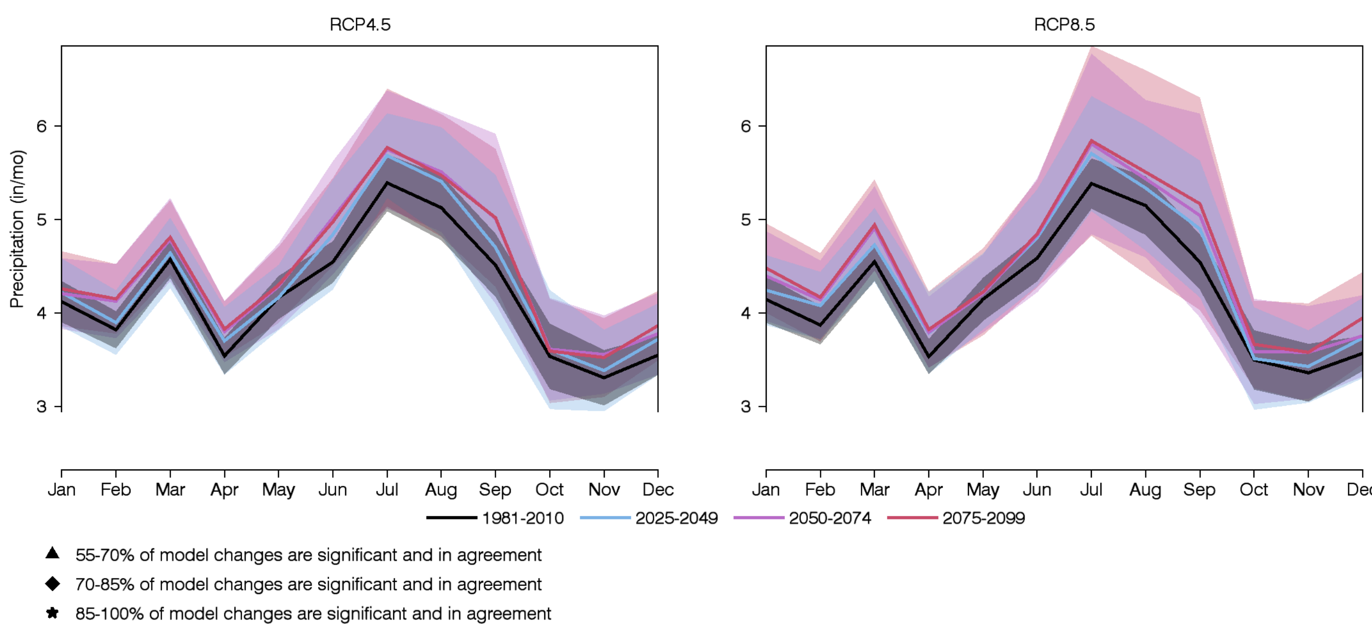


Figure 6: Monthly averages of precipitation for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

4 Snow Water Equivalent

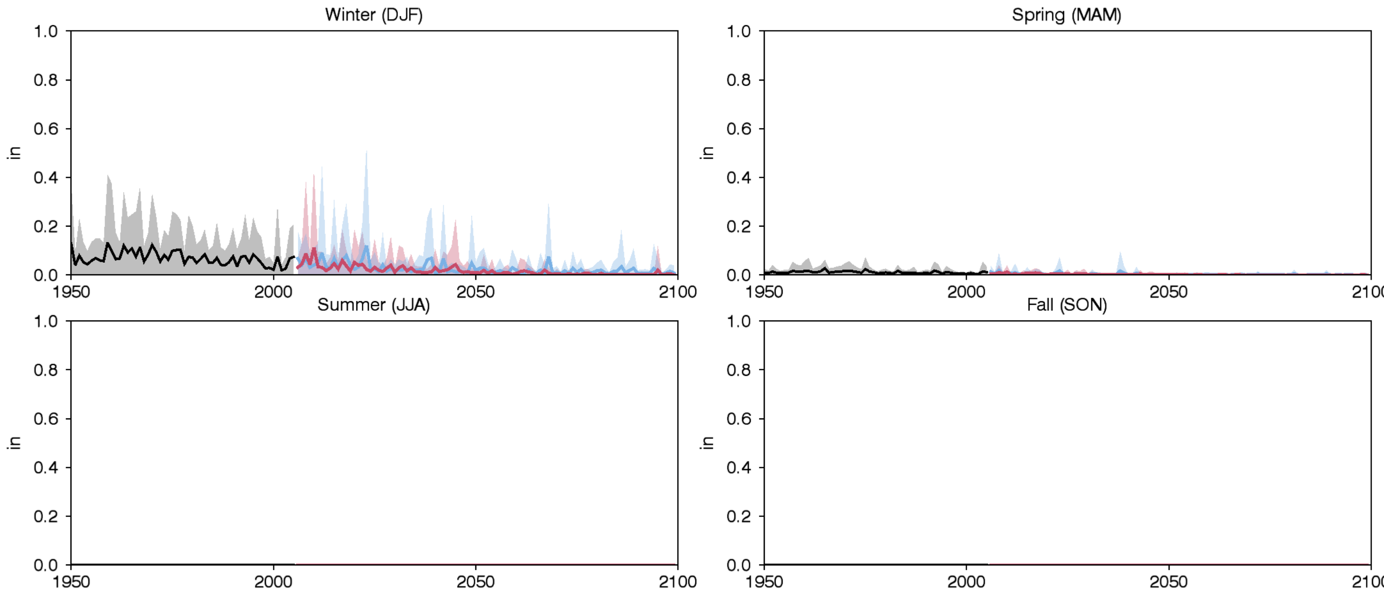


Figure 7: Seasonal average time series of snow water equivalent for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

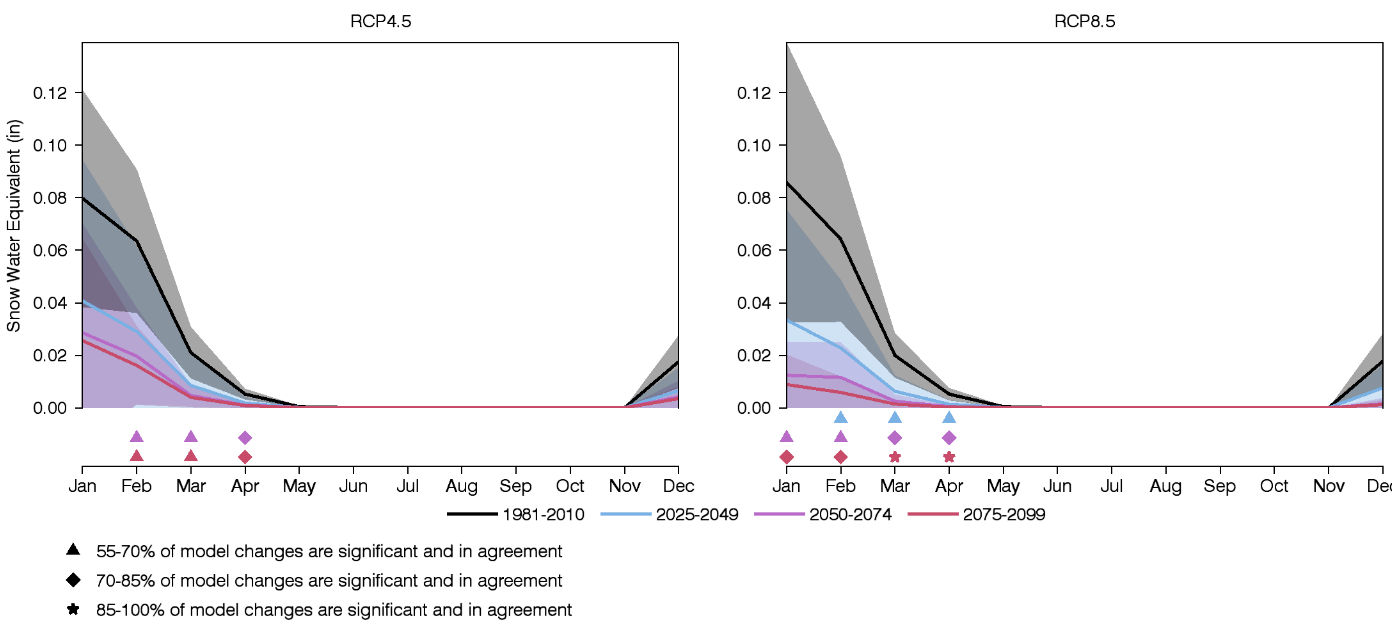


Figure 8: Monthly averages of snow water equivalent for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

5 Runoff

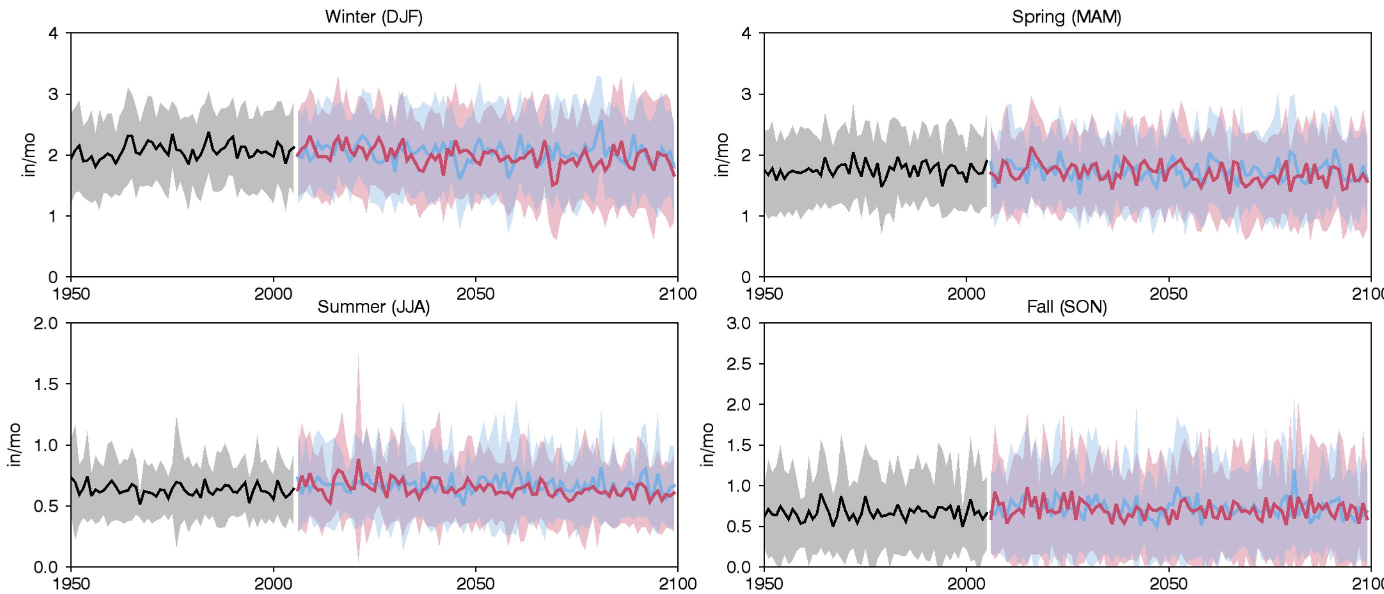


Figure 9: Seasonal average time series of runoff for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

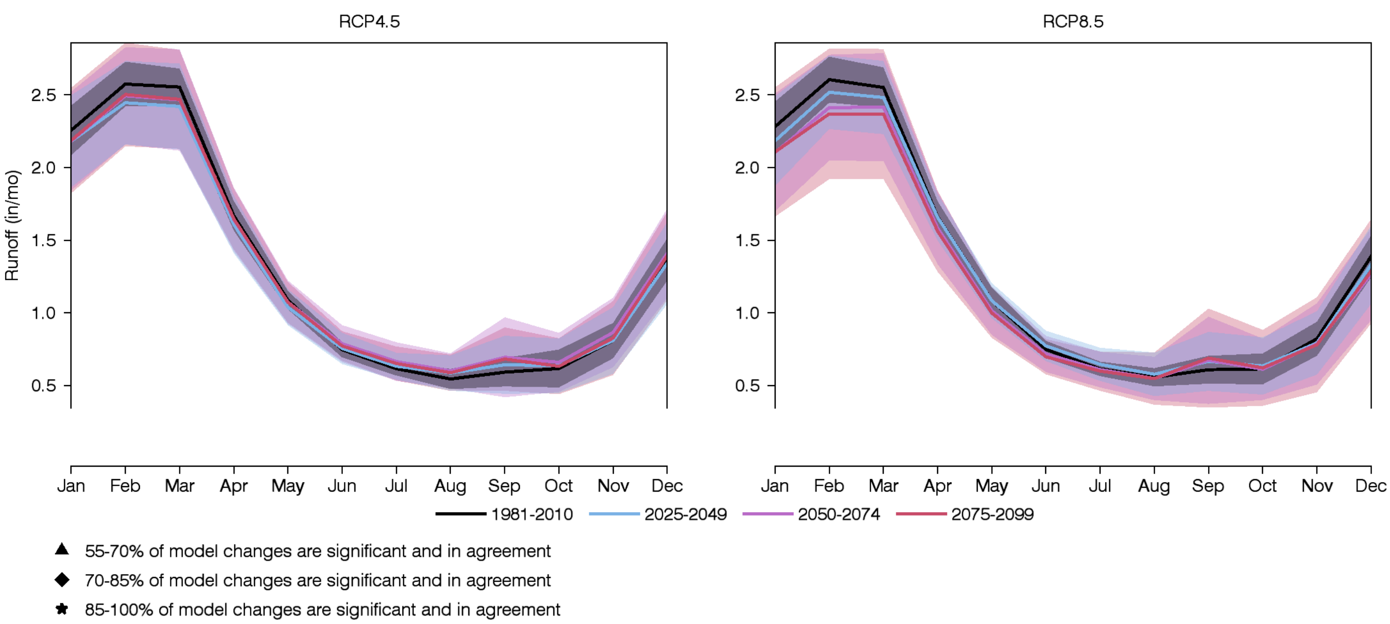


Figure 10: Monthly averages of runoff for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

6 Soil Water Storage

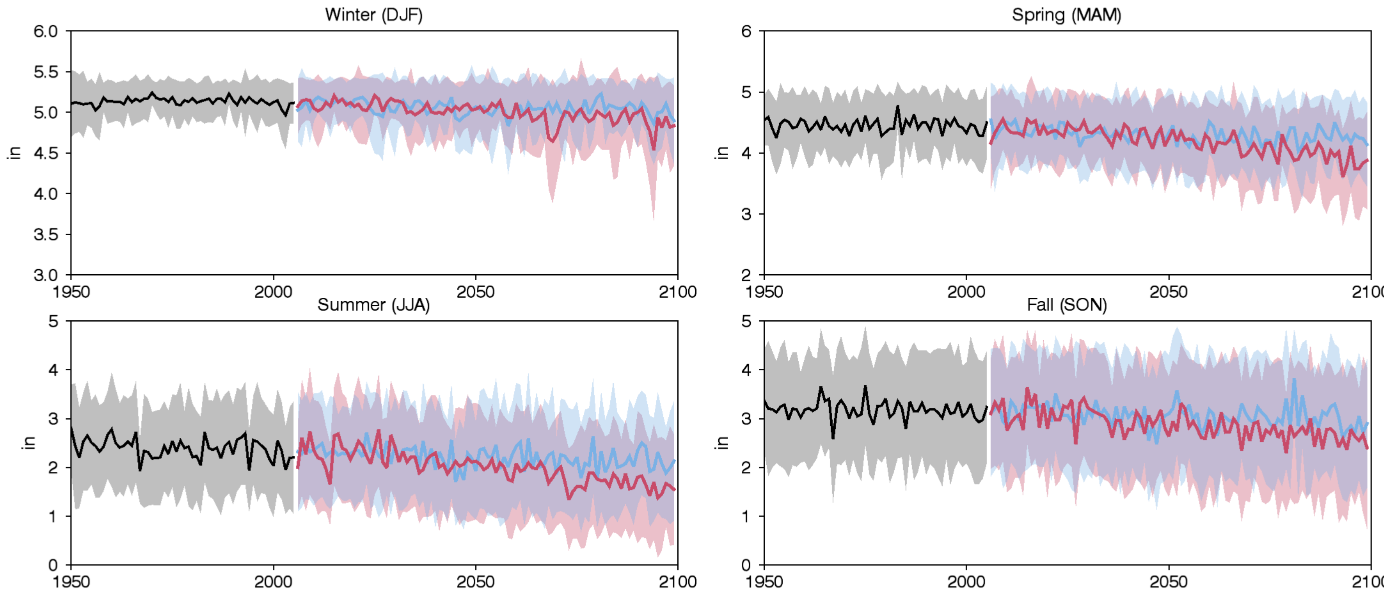


Figure 11: Seasonal average time series of soil water storage for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

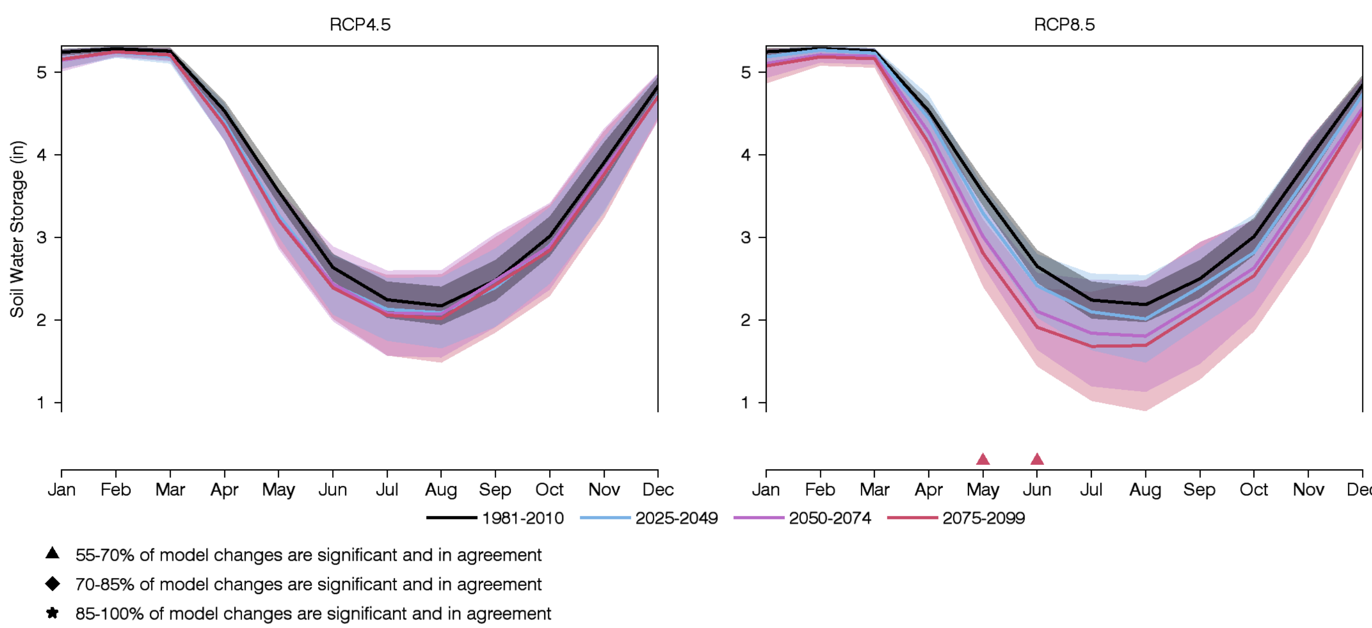


Figure 12: Monthly averages of soil water storage for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

7 Evaporative Deficit

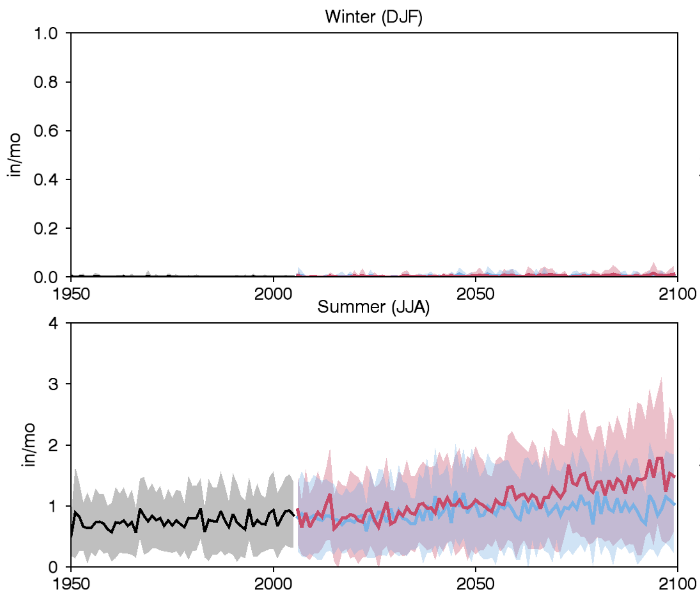


Figure 13: Seasonal average time series of evaporative deficit for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

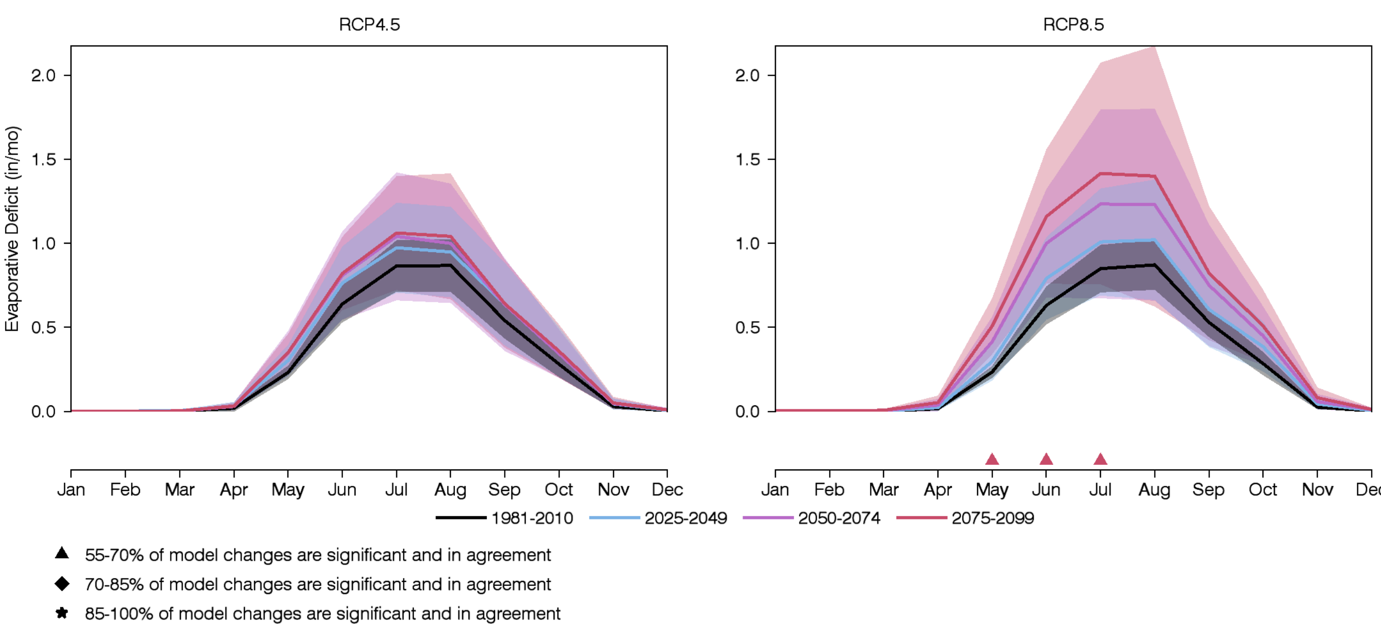


Figure 14: Monthly averages of evaporative deficit for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

8 Data

The temperature and precipitation summaries are created by spatially averaging the NASA NEX-DCP30 data set (Thrasher et al., 2013). The water-balance variables snow water equivalent, runoff, soil water storage and evaporative deficit are simulated by using the NEX-DCP30 temperature and precipitation as input to a simple model (McCabe and Wolock, 2007). The water-balance model accounts for the partitioning of water through the various components of the hydrologic system, but does not account for groundwater, diversions or regulation by impoundments.

9 Models

ACCESS1-0	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4
CESM1-BGC	CMCC-CM	CNRM-CM5	CSIRO-Mk3-6-0	FGOALS-g2	FIO-ESM
GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M	GISS-E2-R	HadGEM2-AO	HadGEM2-CC
HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5
MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MPI-ESM-MR	MRI-CGCM3	NorESM1-M

10 Citation Information

Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer. US Geological Survey http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp doi:10.5066/F7W9575T.

Hostetler, S.W. and Alder, J.R., 2016. Implementation and evaluation of a monthly water balance model over the U.S. on an 800 m grid. Water Resources Research, 52, doi:10.1002/2016WR018665.

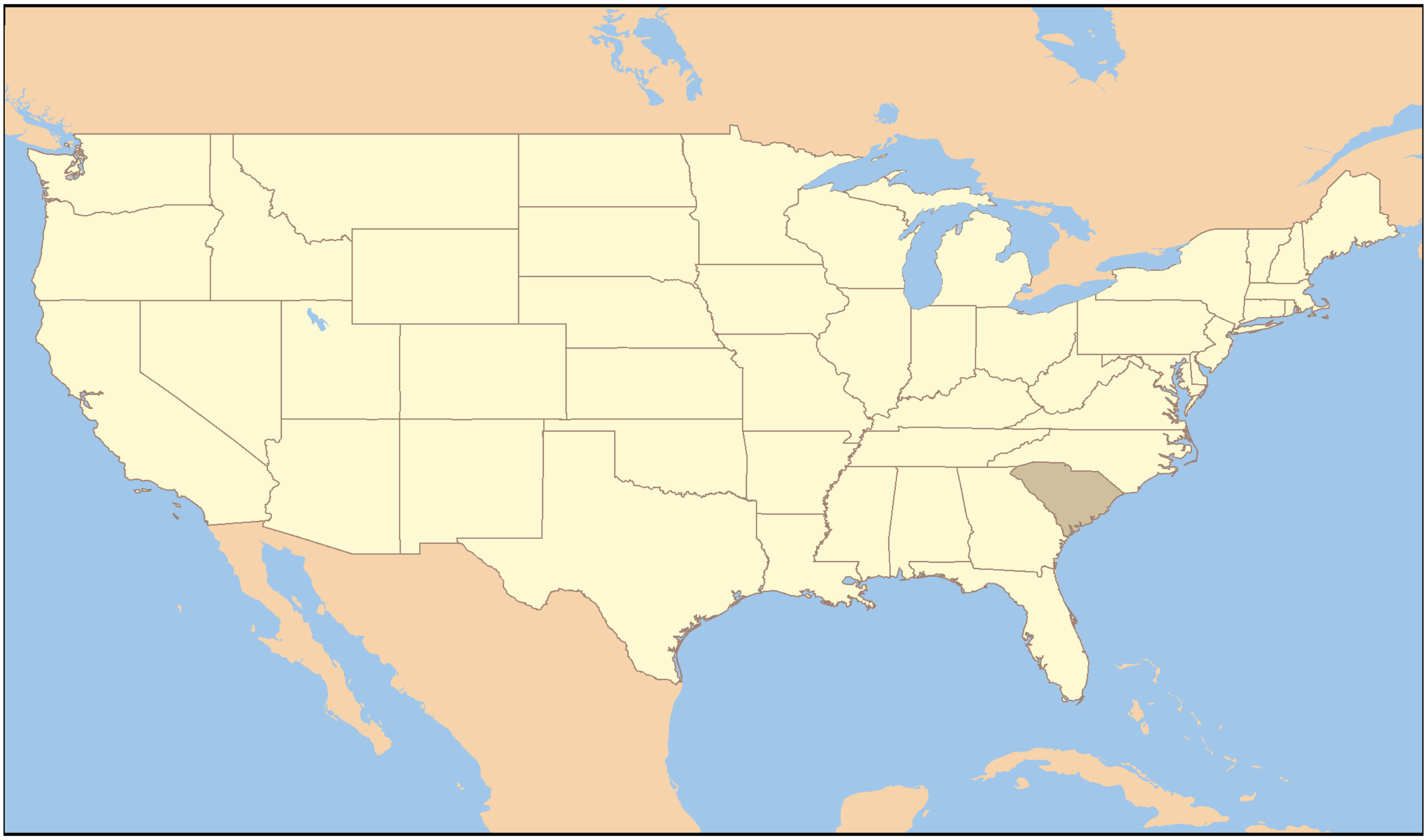
Thrasher, B., J. Xiong, W. Wang, F. Melton, A. Michaelis, and R. Nemani, 2013. New downscaled climate projections suitable for resource management in the U.S. Eos, Transactions American Geophysical Union 94, 321-323, doi:10.1002/2013EO370002.

11 Disclaimer

These freely available, derived data sets were produced by J. Alder and S. Hostetler, US Geological Survey (USGS). The original climate data are from the NEX-DCP30 dataset, which was prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and is distributed by the NASA Center for Climate Simulation. No warranty expressed or implied is made by the USGS regarding the display or utility of the derived data on any other system, or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. The USGS shall not be held liable for improper or incorrect use of the data described and/or contained herein.

U.S. Geological Survey - National Climate Change Viewer

Summary of South Carolina



December 1, 2016

1 Maximum 2-m Air Temperature

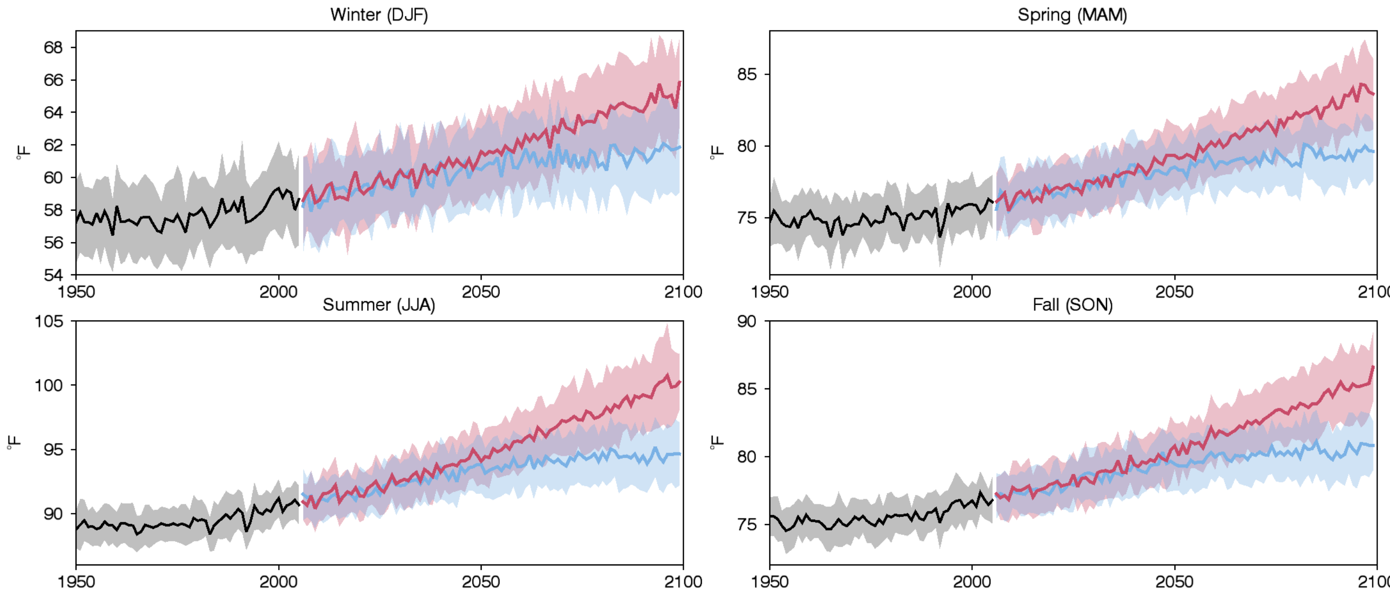


Figure 1: Seasonal average time series of maximum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

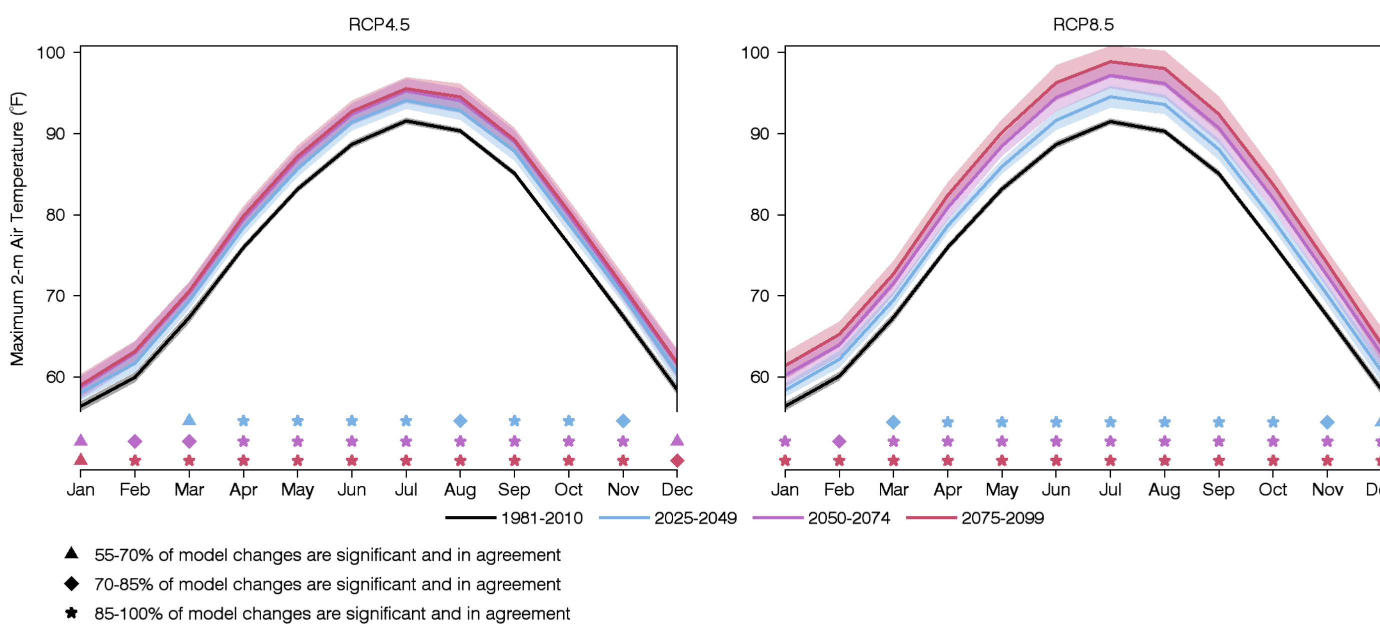


Figure 2: Monthly averages of maximum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

2 Minimum 2-m Air Temperature

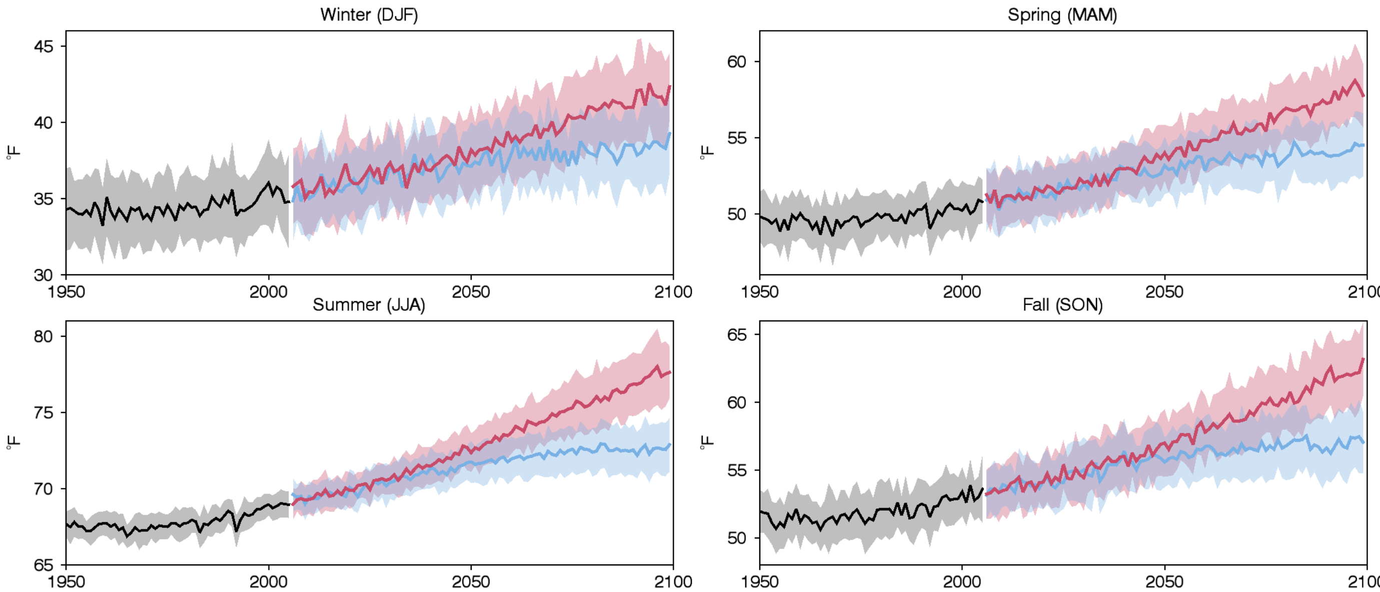


Figure 3: Seasonal average time series of minimum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

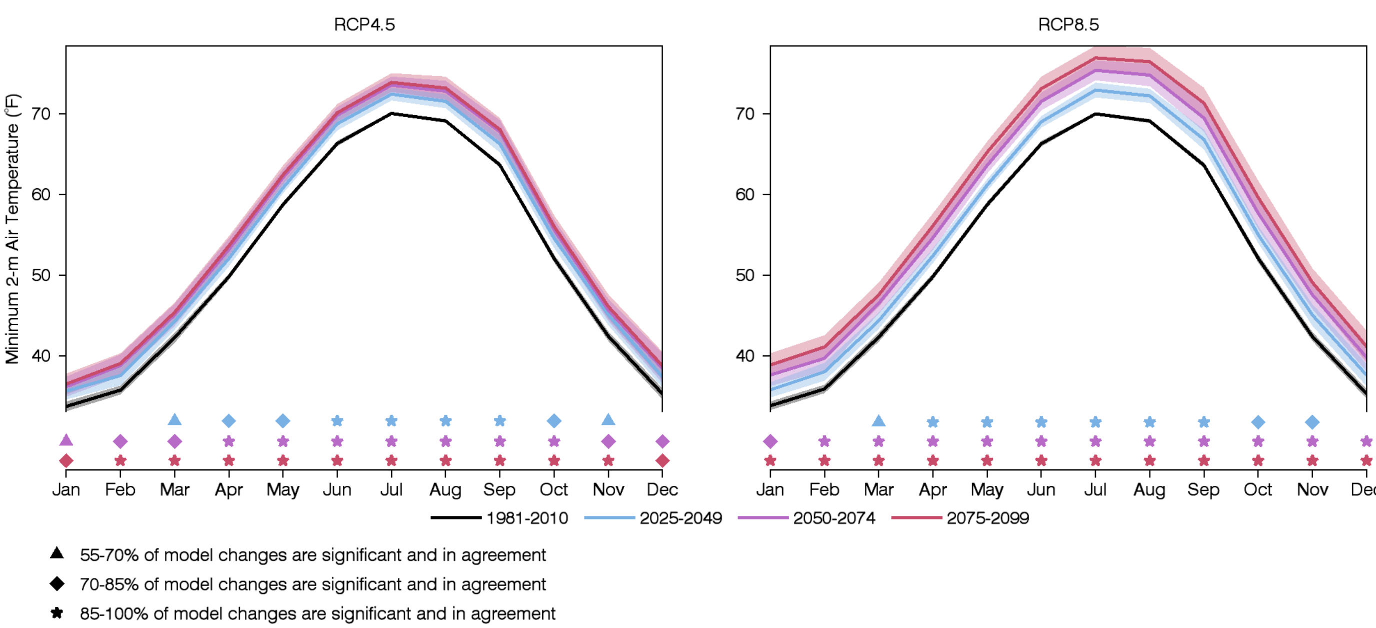


Figure 4: Monthly averages of minimum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

3 Precipitation

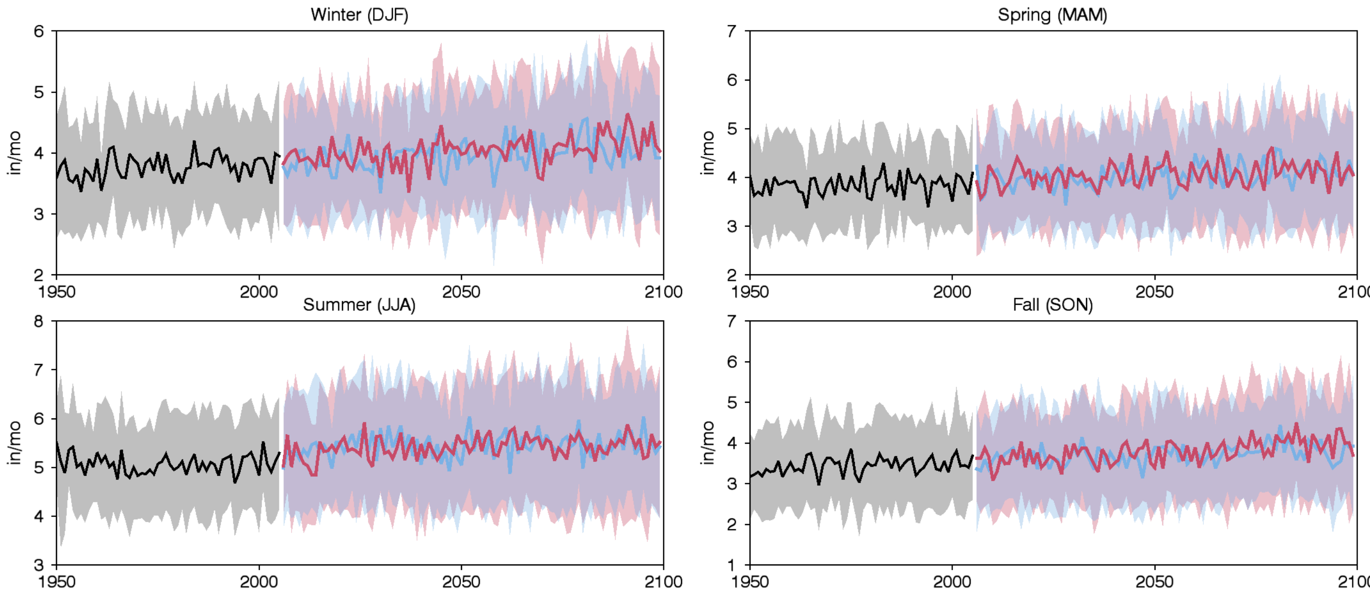


Figure 5: Seasonal average time series of precipitation for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

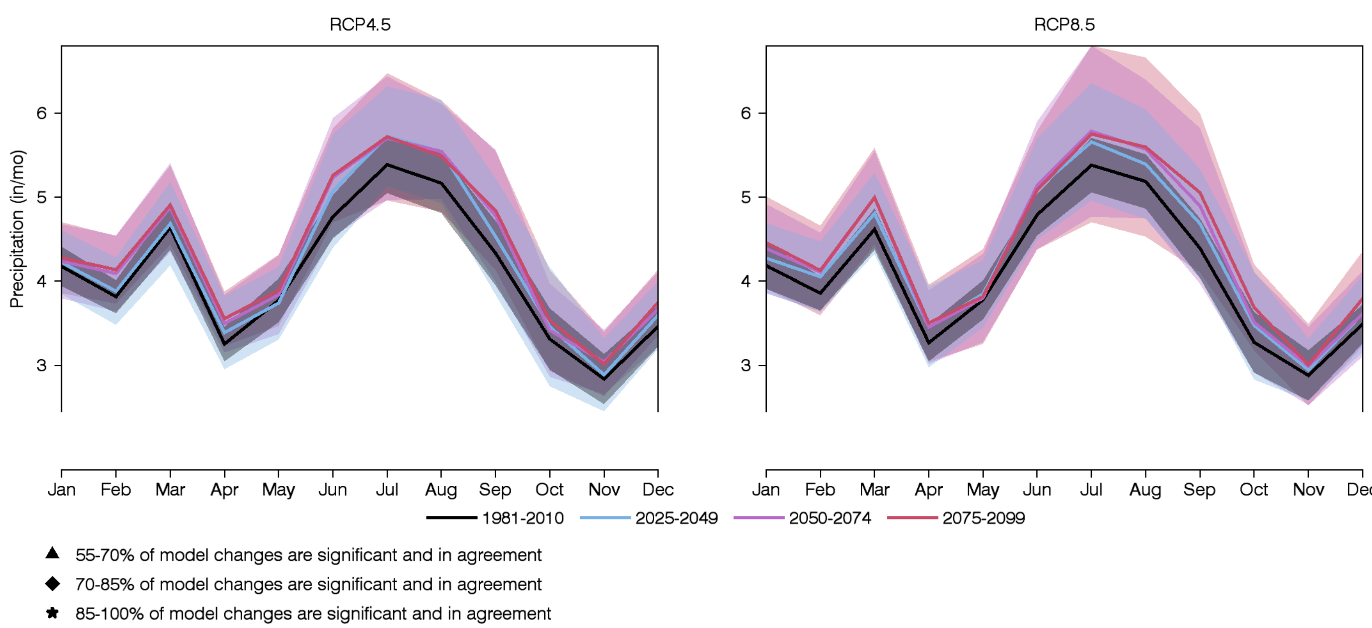


Figure 6: Monthly averages of precipitation for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

4 Snow Water Equivalent

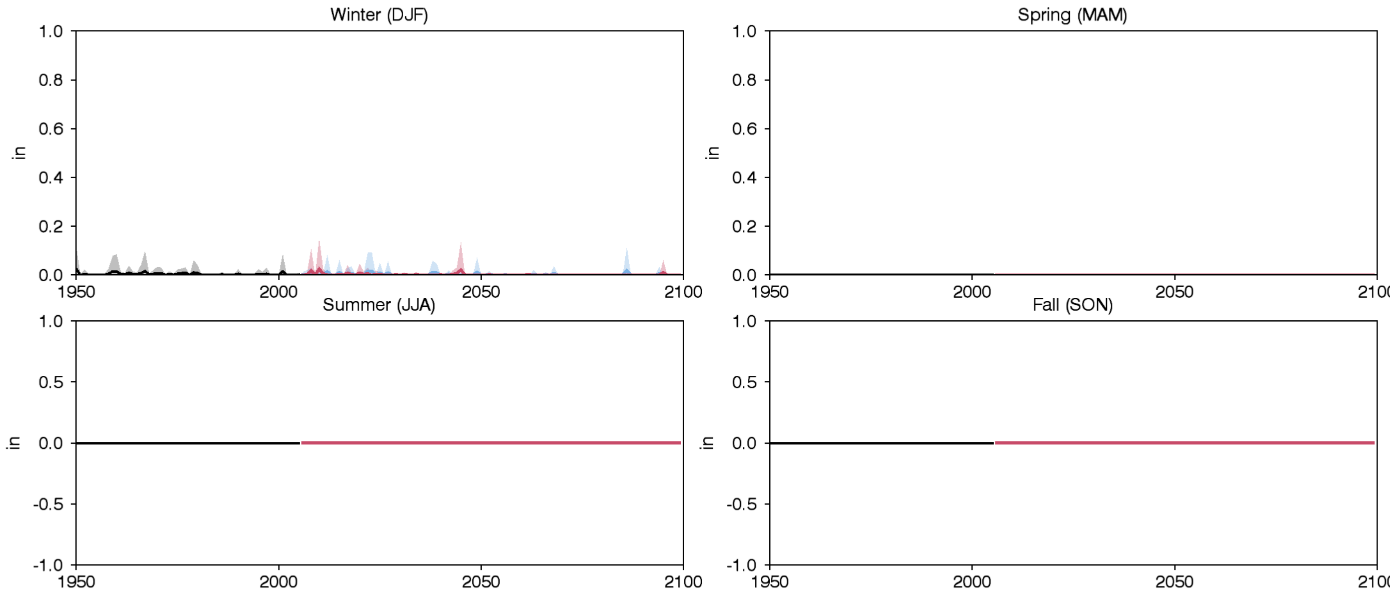


Figure 7: Seasonal average time series of snow water equivalent for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

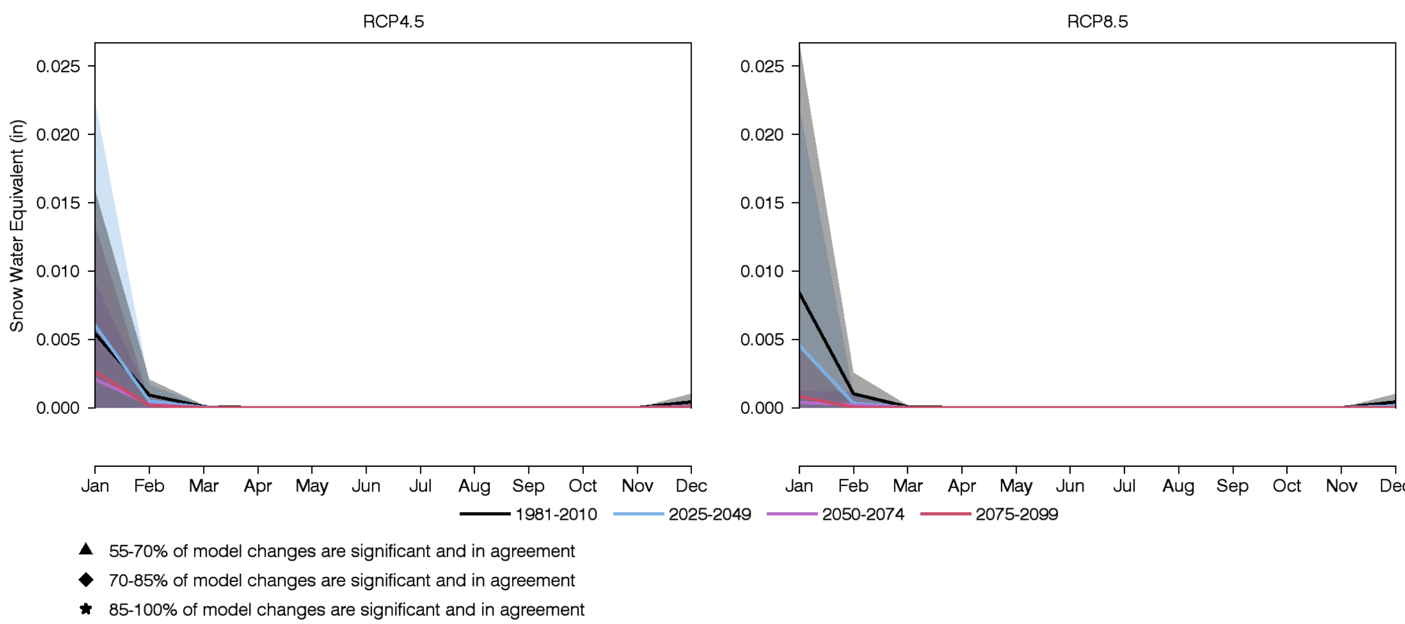


Figure 8: Monthly averages of snow water equivalent for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

5 Runoff

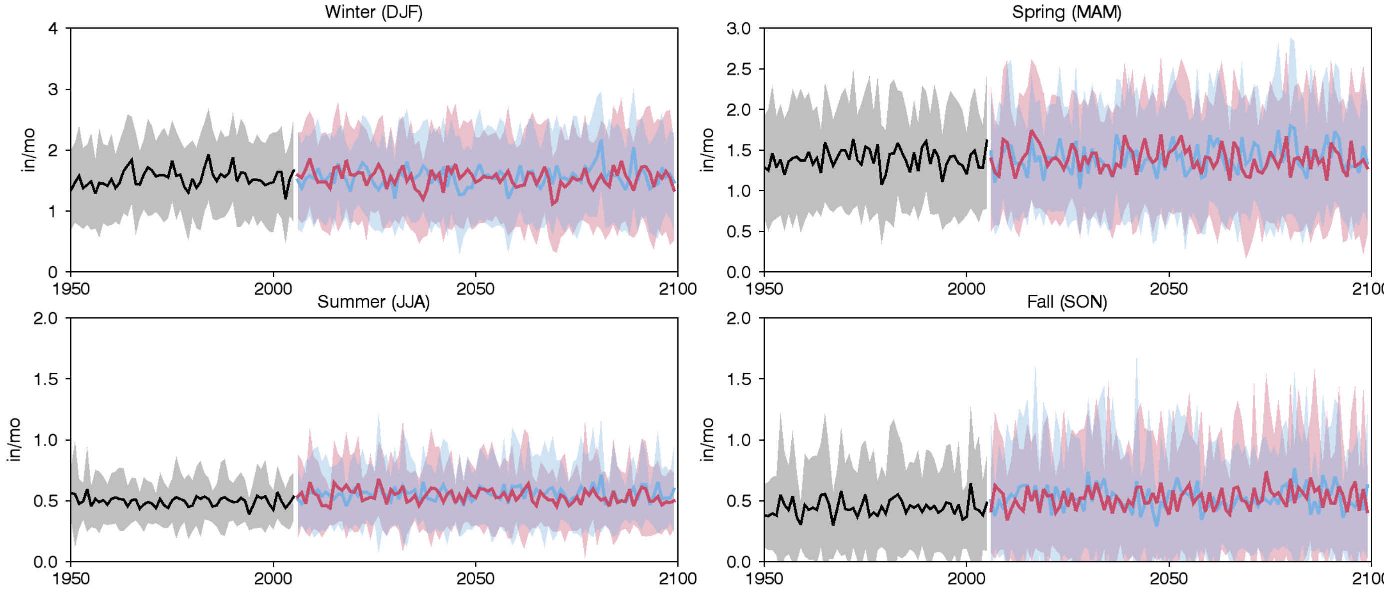


Figure 9: Seasonal average time series of runoff for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

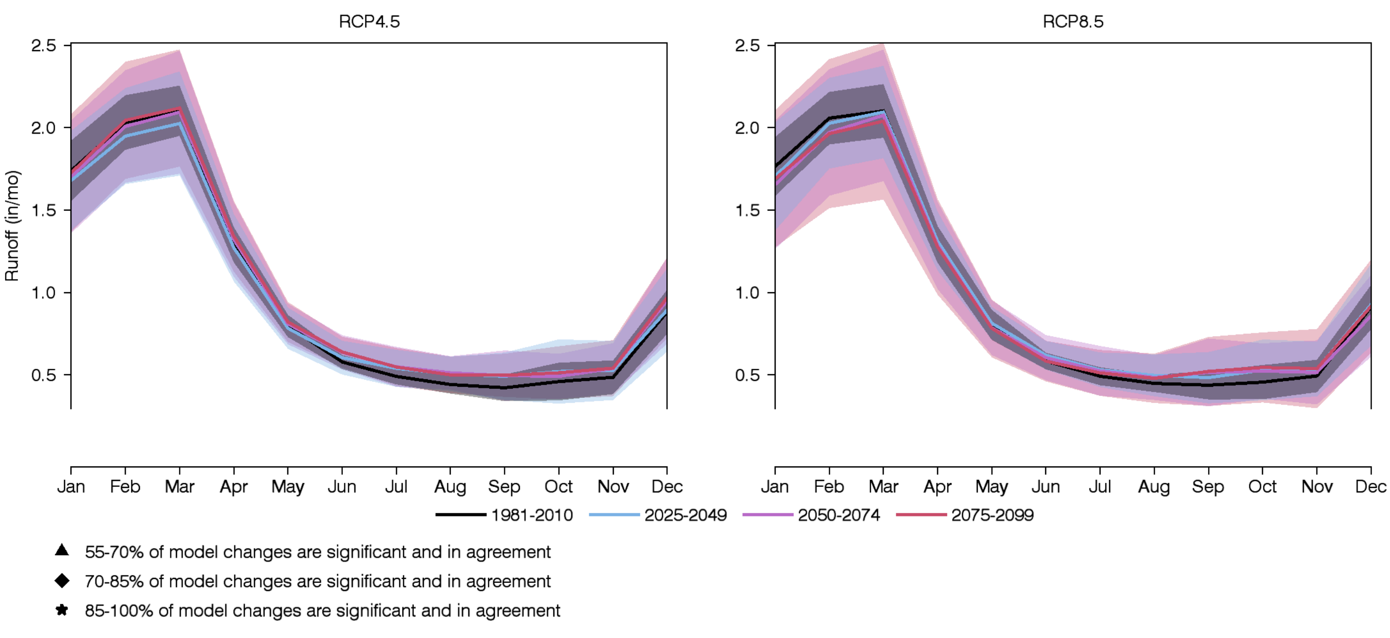


Figure 10: Monthly averages of runoff for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

6 Soil Water Storage

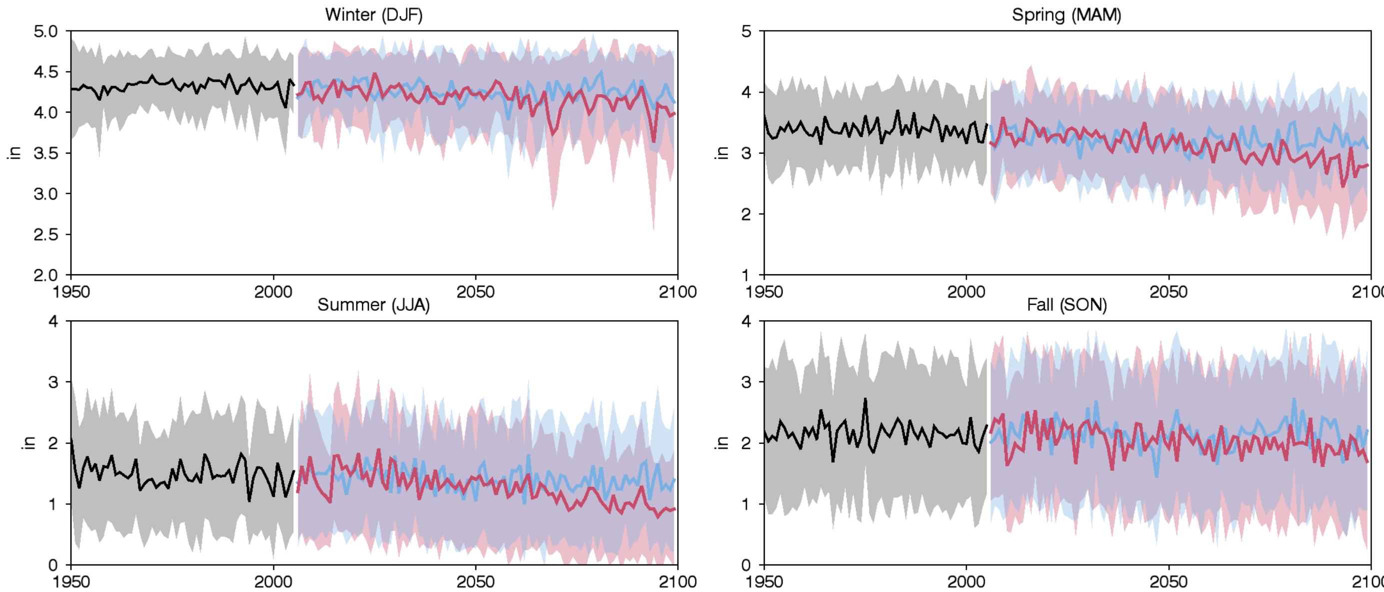


Figure 11: Seasonal average time series of soil water storage for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

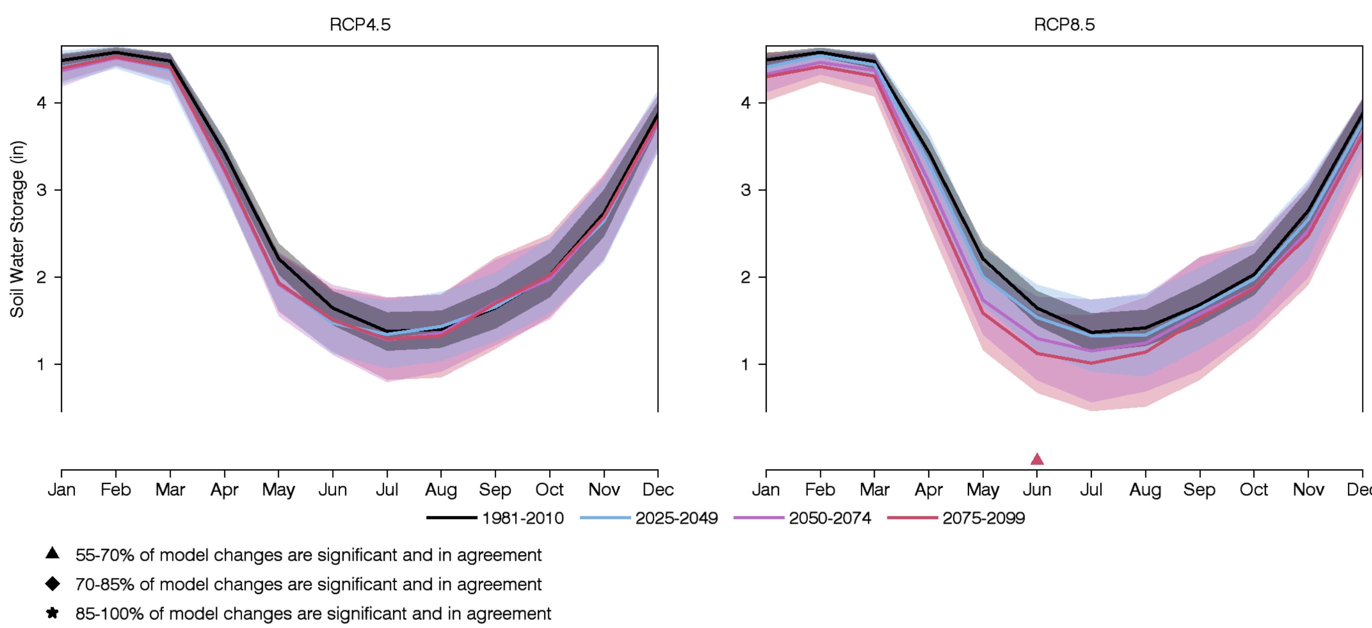


Figure 12: Monthly averages of soil water storage for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

7 Evaporative Deficit

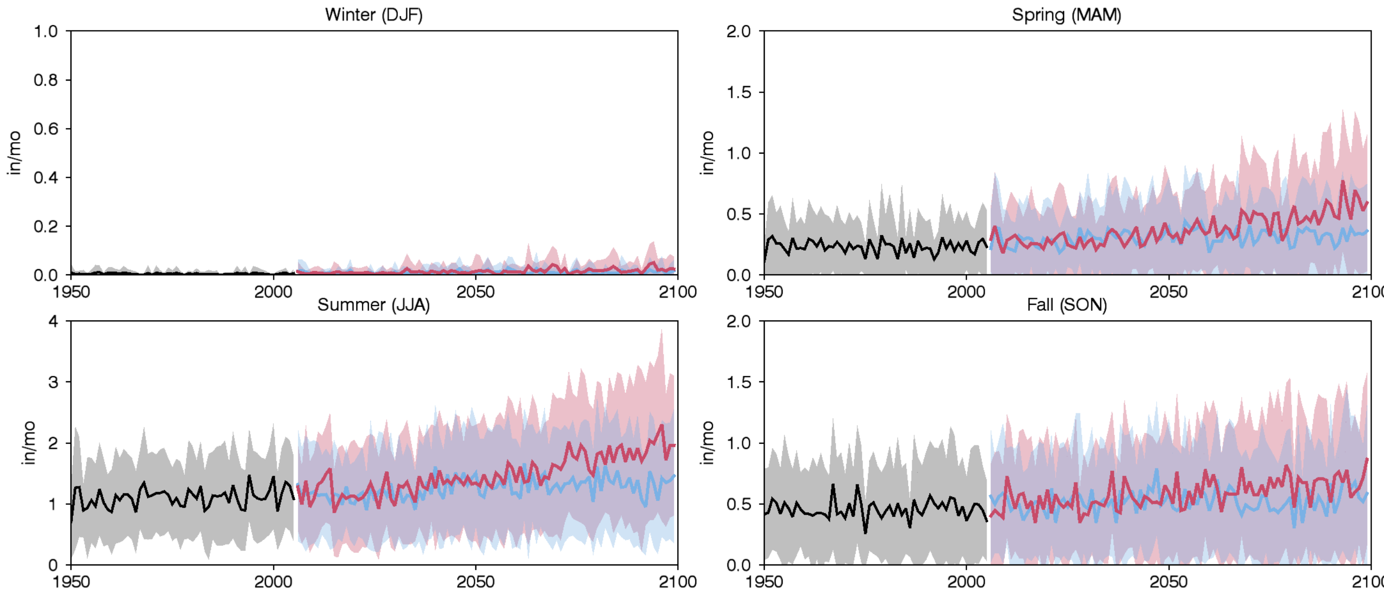


Figure 13: Seasonal average time series of evaporative deficit for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

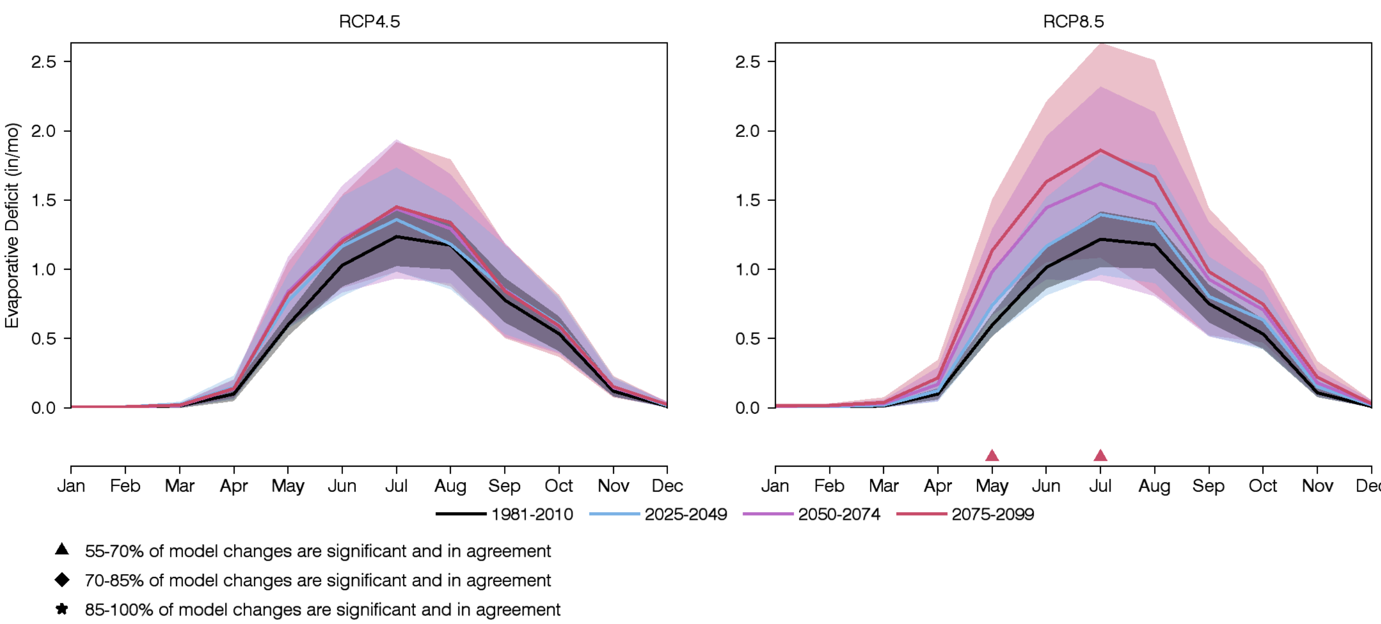


Figure 14: Monthly averages of evaporative deficit for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

8 Data

The temperature and precipitation summaries are created by spatially averaging the NASA NEX-DCP30 data set (Thrasher et al., 2013). The water-balance variables snow water equivalent, runoff, soil water storage and evaporative deficit are simulated by using the NEX-DCP30 temperature and precipitation as input to a simple model (McCabe and Wolock, 2007). The water-balance model accounts for the partitioning of water through the various components of the hydrologic system, but does not account for groundwater, diversions or regulation by impoundments.

9 Models

ACCESS1-0	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4
CESM1-BGC	CMCC-CM	CNRM-CM5	CSIRO-Mk3-6-0	FGOALS-g2	FIO-ESM
GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M	GISS-E2-R	HadGEM2-AO	HadGEM2-CC
HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5
MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MPI-ESM-MR	MRI-CGCM3	NorESM1-M

10 Citation Information

Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer. US Geological Survey `http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp` doi:10.5066/F7W9575T.

Hostetler, S.W. and Alder, J.R., 2016. Implementation and evaluation of a monthly water balance model over the U.S. on an 800 m grid. Water Resources Research, 52, doi:10.1002/2016WR018665.

Thrasher, B., J. Xiong, W. Wang, F. Melton, A. Michaelis, and R. Nemani, 2013. New downscaled climate projections suitable for resource management in the U.S. Eos, Transactions American Geophysical Union 94, 321-323, doi:10.1002/2013EO370002.

11 Disclaimer

These freely available, derived data sets were produced by J. Alder and S. Hostetler, US Geological Survey (USGS). The original climate data are from the NEX-DCP30 dataset, which was prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and is distributed by the NASA Center for Climate Simulation. No warranty expressed or implied is made by the USGS regarding the display or utility of the derived data on any other system, or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. The USGS shall not be held liable for improper or incorrect use of the data described and/or contained herein.

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 (NCNHP 2016a; NCNHP 2016b), the species consists of 113 populations distributed across 12 counties in North Carolina and South Carolina. Recent genetic research 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 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.

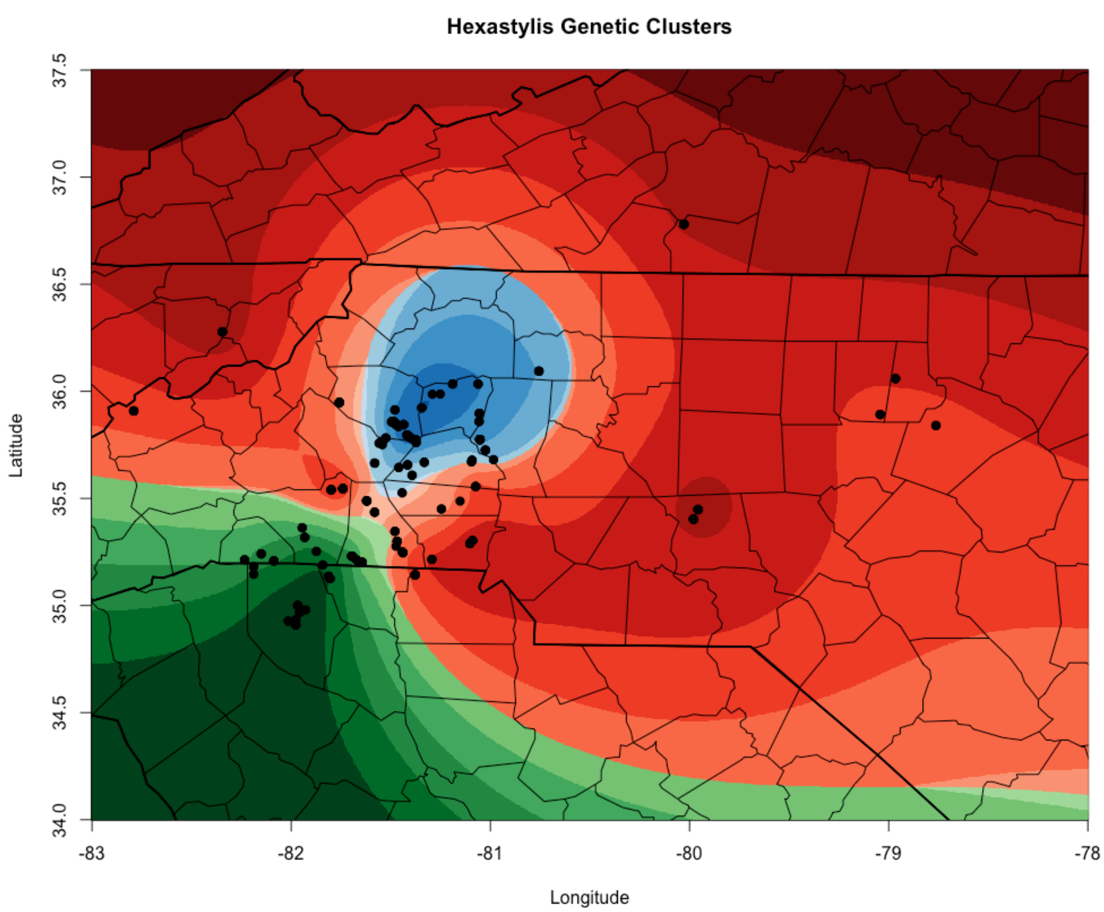


Figure 1-Recent genetic analyses detailing clustering of the genus Hexastylis. Green areas represent "true" *H. naniflora*; Blue represents a possible new species; Red represents other species in the genus (*H. minor, H. heterophylla*, etc.).

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 of years since the species was last observed at a given location (1964-2017), so although recent reports suggest the species consists of 113 populations, some of that data is fairly outdated. For the purposes of this SSA, we only used EO that were observed within the last 10 years (2007-2017). Based on that criteria, there are currently 68 populations distributed across the range of dwarf-flowered heartleaf, although this may be an underestimate as discussed in more detail in the habitat modelling section later.

To determine overall resilience for populations, we used EO viability ranks and expert opinion to bin population size classes into corresponding resilience categories. EO viability ranks for the species include excellent, good, fair, poor, extant, historical, and failed to find. The primary factor in determining these ranks is EO size (as quantified by number of clumps). Condition of habitat (vegetation community and structure) and landscape context (extent of suitable habitat and physical factors) are also incorporated secondarily. Appendix 1 shows the NCNHP EO rank specifications for dwarf-flowered heartleaf. The EO rank specifications suggest good-excellent viability for populations consisting of at least 500 individuals, given there is sufficient high quality habitat; fair viability for populations consisting of 100-500 individuals, depending on habitat conditions; poor viability for populations consisting of less than 100 individuals. Recent

reports (NCNHP 2016a; NCNHP 2016b) focus monitoring studies on populations with greater than 1,000 individuals, populations that are assumed to be very viable. Because we do not have habitat level information for every population we assessed, we synthesized all of the 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, and moderate-high probability of extirpation for 20-30 years at or above the current population size.

Occupancy and Abundance

There are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years (Table 1), and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low). Table 2 shows the contribution of each resilience category as follows: 40% (very high); 7% (high); 30% (moderate); 22% (low). When looking at cumulative percentages of resilience, it is interesting to note that 78% of all of the populations are classified as moderate to very high resilience (Table 2).

Table 1--Current populations of dwarf-leafed heartflower and associated resilience across the species range.

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

Cowpens NBF - Site 1	South Carolina	Cherokee	2016	>1000	very High
Cliffside Steam Station	North Carolina	Clev/Ruth	2016	>1000	very high
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	>1000	very high
Broad River: Brushy Creek	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Kings Mountain Res	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Tributaries N and S of SR 2047	North Carolina	Cleveland	2012	>1000	very high
Rhyne Conservation Preserve	North Carolina	Lincoln	2016	>1000	very high
Mill Creek Forest and Seep	North Carolina	Polk	2016	>1000	very high
New Hope Springhead Swamp	North Carolina	Polk	2016	>1000	very high
Big Horse Creek Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Broad River: Floyds Creek	North Carolina	Rutherford	2016	>1000	very high
Davenport Road/Mountain View Rare Plant Site	North Carolina	Rutherford	2016	>1000	very high
Facebook Site	North Carolina	Rutherford	2016	>1000	very high
Floyds Creek Tributray Rare Plant Site	North Carolina	Rutherford	2012	>1000	very high
New Bethel Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Richardson Creek trib above Toms Lake	North Carolina	Rutherford	2016	>1000	very high
DNR Peters Creek Heritage Preserve	South Carolina	Spartanburg	2016	>1000	very High
Taylor Blalock Res	South Carolina	Spartanburg	2016	>1000	very High
Little Gunpowder Creek Rare Plant Site 1	North Carolina	Caldwell	2015	500-1000	high
Little Gunpowder Creek Rare Plant Site 2	North Carolina	Caldwell	2015	500-1000	high
Northern Catawba County	North Carolina	Catawba	2017	500-1000	high
Rock Barn Solar Farm	North Carolina	Catawba	2010-2011	500-1000	high
Buffalo Creek Rare Plant Site	North Carolina	Cleveland	2012	500-1000	high
Third Creek Rare Plant Site	North Carolina	Alexander	2010	100-500	moderate
Hickory Area	North Carolina	Burk/Cata/Cald	2016	100-500	moderate
Burke County - Drowning Creek UT	North Carolina	Burke	2017	100-500	moderate
Simms Hill/Little River Uplands	North Carolina	Burke	2015	100-500	moderate
Smith Cliff/Henry Fork River	North Carolina	Burke	2015	100-500	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork Catawba River Jacobs Fork and Camp Creek	North Carolina	Catawba	2016	100-500	moderate
NCDOT TIP R-2824	North Carolina	Catawba	2015	100-500	moderate
South Fork Catawba River, Henry Fork	North Carolina	Catawba	2007	100-500	moderate
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	100-500	moderate
Brushy Creek Headwaters	North Carolina	Cleveland	2014	100-500	moderate
First Broad River: Crooked Run Creek	North Carolina	Cleveland	2010	100-500	moderate
No Business Creek, Boyd Tract	North Carolina	Cleveland	2007	100-500	moderate
West Shelby Mesic Slope	North Carolina	Cleveland	2016	100-500	moderate
UT of Kings Mountain Res	North Carolina	Gaston	2012	100-500	moderate
Buffalo Shoals Creek	North Carolina	Iredell	2014	100-500	moderate
Cat Square Heartleaf Forest	North Carolina	Lincoln	2012	100-500	moderate
Collinsville (Hughes) Creek Slopes	North Carolina	Polk	2016	100-500	moderate
Fox Knoll Farm	North Carolina	Polk	2016	100-500	moderate
Forest City: Adj to Isothermal CC	North Carolina	Rutherford	2010	100-500	moderate
Jonas Road Rare Plant Site	North Carolina	Rutherford	2014	100-500	moderate
NCDOT TIP R-3603A	North Carolina	Alexander	2017	<100	low
South Mountains Pleasant Grove Uplands	North Carolina	Burke	2016	<100	low

Gunpowder Creek	North Carolina	Caldwell	2012	<100	low
Killian Crossroads	North Carolina	Catawba	2010	<100	low
Pott Creek	North Carolina	Catawba	2012	<100	low
Beaverdam Crk at First Broad River	North Carolina	Cleveland	2011	<100	low
Buffalo Creek: Potts Creek	North Carolina	Cleveland	2012	<100	low
Buffalo Creek: Ravine	North Carolina	Cleveland	2007	<100	low
Hickory Creek - UT (Shelby High School)	North Carolina	Cleveland	2016	<100	low
Boulder Creek Subdivision - Jordan Road	South Carolina	Greenville	2016	<100	low
Gateway Elementary School	South Carolina	Greenville	2017	<100	low
Fanjoy Road Site	North Carolina	Iredell	2015	<100	low
Levan Family Farm	North Carolina	Iredell	2013	<100	low
Lincoln County, SR-1314	North Carolina	Lincoln	2014	<100	low
Northeast Lincolnton: UT Walker Branch	North Carolina	Lincoln	2009	<100	low

Table 2--Population resilience categories by county for dwarf-flowered heartleaf.

County	**Very High**	**High**	**Moderate**	**Low**	**Totals**
Alexander	1		1	1	3
Burk/Cata/Cald			1		1
Burke	2		3	1	6
Caldwell	2	2		1	5
Catawba	4	2	3	2	11
Cherokee	1				1
Clev/Ruth	1				1
Cleveland	4	1	5	4	14
Gaston			1		1
Greenville				2	2
Iredell			1	2	3
Lincoln	1		1	2	4
Polk	2		2		4
Rutherford	7		2		9
Spartanburg	2				2
Totals	**27**	**5**	**20**	**15**	**67**
% of total	*40*	*7*	*30*	*22*	*100*
Cumulative %	*40*	*48*	*78*	*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 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 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: NCNHP).

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	Rhyne 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
	NCNHP	Broad River: Henson's Creek, Brice, & Sandy Mush Outcrop (EO 099)	106,940	83.39
	NCNHP	Broad River: Cleghorn Creek, US 221 (EO 176)	6,750	7.24
	NCNHP	Cowpens National Battlefield (SC EO 016, 017, 018)	2,823	6.05
	NCNHP	Peters Creek Preserve (SC EO 011)	3,306	8.98
	NCNHP	Blalock Reservoir (SC EO 007, 031)	3,505	7.59
Decreasing	NCNHP	Second Broad River (Forest City Industrial Complex) (EO 154)	2,576	4.74
	NCNHP	South Fork Catawba River: Jacob Fork, Camp Creek (EO 158)	123	0.09

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

A previous habitat suitability study attempted to quantify the habitat requirements for dwarf-flowered heartleaf. A model was created to predict habitat suitability, and based on the model results, the strongest habitat correlations were slope, aspect, soil type, elevation, and land use (Wagner 2015). With this model in mind, 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 2.

Source Data and Model Variables

Fifty three, 10-digit hydrologic units (HUC) comprise the analysis extent. In North Carolina, it includes all 10-digit HUC that fall within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*. In South Carolina, we also included all 10-digit HUC that fell within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*, 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. These data were in polygon format and digitized at a scale that accurately identified the boundaries of the individual population areas. 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 in the last 10 years (2007). 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.

Model Development

We used Maxent software (version 3.4.1) for species habitat modeling (Philips 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, SSURGO drainage class, SSURGO hydrologic group, aspect 9-class, aspect 5-class, slope, and maximum annual temperature.

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 2 shows the model output. The minimum cutoff value (to determine if an area is considered potential habitat for a species) of 0.406 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 predictions to focus on the typical habitat conditions for this species. The total area ranked greater than 0.406 in the Maxent model was just 6.39% of the total analysis area (Table 4).

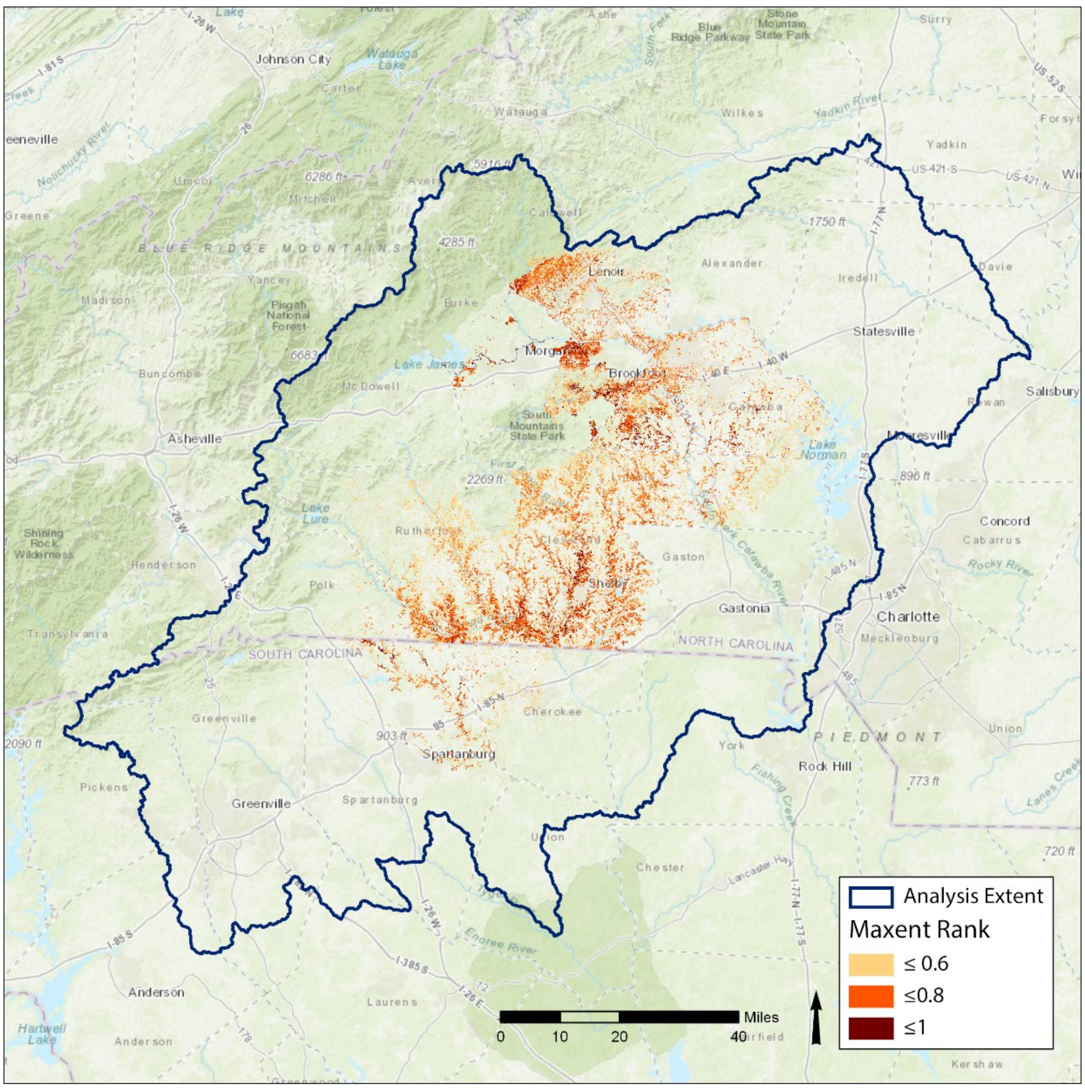


Figure 2-Maxent model output map

Table 4-Area estimates of the Maxent model

Maxent Score	Acres	Square Miles	Percent of Total
0.406 and greater	321,262.37	501.97	6.39%
0.6 and greater	146,712.65	229.24	2.92%
0.8 and greater	22,677.96	35.43	0.45%

The average area-under-curve (AUC) score for the replicate Maxent model is 0.849. The AUC is calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1 and may be interpreted as a single test statistic that assesses model performance, indicating the ability of the model to correctly classify the occurrence data used. The model performed well in its predictions, with a mean AUC of 0.849 (AUC value of 0.5 is no better than random; AUC<0.5 is worse than random; AUC>0.5 is greater predictive power than random; Baldwin 2009).

The Maxent output supplies estimates of the relative contributions of the environmental variables to the Maxent model (Table 5). SSURGO mukey is the top contributing variable. One hundred and thirty-five individual soil types are present within the polygon boundaries of the *Hexastylis naniflora* element occurrences. Many of these individual soil types are part of soil complexes and are separated by things such as percent slope, erosion, how stony/rocky, and amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25 to 60 percent slopes, very stony (12.9% of total). However, collectively the Meadowfield soils only comprised 13.5% of all soils). The individual Pacolet soil types were very common and collectively comprise 36% of all soil types present. Woolwine soils were also collectively common, comprising 10% of all soils present.

The minimum annual average temperature range in the analysis extent is 39 – 51 degrees Fahrenheit. The majority of the *Hexastylis naniflora* element occurrences (92%) 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 (81%) are found in the 47 – 49 inches per year range.

Piedmont forested landcover habitats dominate the land area of the element occurrences. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier (52%), Southern Piedmont Mesic Forest (10%), Southern Piedmont Small Floodplain and Riparian Forest (3.6%), and Southern Piedmont Dry Oak-Pine Forest – Loblolly Pine Modifier (2.3%) collectively comprise 72% of the element occurrences area. Unfortunately, non-native habitats are also present. Evergreen Plantation or Managed Pine (8%), Harvested Forest – Grass/Forb Regeneration (7%), Developed, Open Space (5%), Pasture/Hay (2.5%) 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 landcover classes, but each at small percentages.

The landcover majority classification scheme reduces the total number of landcover classes present in the analysis extent from 23 to 12. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landcover class (56%). 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 landcover area representation in the landcover majority layer suggests that many *Hexastylis naniflora* population areas are situated in areas impacted by disturbed landcover. This is likely due to urban encroachment and increasing fragmentation of habitats.

The landcover Hexastylis grouping reveals the amount of disturbance present in Hexastylis population areas. Landcover classes grouped as disturbed comprises 26% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, hardwood forest 11%, and riparian 3.6%. Open water, evergreen and barren landcover groupings are all at less than 1% each.

Geomorphons revealed that the majority of *Hexastylis naniflora* element occurrence areas are situated in concave landforms. Geomorphon categories hollow (15%), valley (35%), and depression (17%) collectively comprise 67% of all *Hexastylis naniflora* population areas. Flat landforms comprise 22.5% of the area and convex landforms the remaining 10.5%.

Within the analysis extent, the range of elevation present is 335 – 5,265 feet. For *Hexastylis naniflora*, the prime elevation range is from 666 – 896 feet (54% of total element occurrence area). A lesser elevation range is present from 935 – 1,165 (35% of total element occurrence area).

Table 5-Percent contribution of the environmental variables

Environmental Variable	Percent Contribution
SSURGO mukey	23.3%
Minimum Annual Temperature	20.7%
Average Annual Precipitation	14.6%
Landcover	13%
Landcover Majority	9.5%
Landcover Hexastylis Grouping	7.3%
Geomorphons	6.4%
Elevation	5.2%

We performed an Analysis of Variance test to investigate the relationship between Maxent scores and current resilience of populations (Table 6). There are significant differences in the average Maxent scores between the four resilience categories ($p = 0.01$) and the mean Maxent score increases as population resilience increases for low to very high. It appears the model gives us some predictive ability regarding habitat quality, where higher Maxent scores, on average, result in higher population resilience.

Table 6-Results of the ANOVA investigating relationships between Maxent scores and current resilience groups for dwarf-flowered heartleaf.

Groups	*Count*	*Sum*	*Average*	*Variance*
low	13	5.240363	0.403105	0.124194
moderate	20	8.851696	0.442585	0.040139
high	4	2.292114	0.573028	0.039821
very high	27	16.66603	0.61726	0.020717

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.563333	3	0.187778	3.870253	0.01346	2.758078
Within Groups	2.911089	60	0.048518			
Total	3.474421	63				

Current Species Representation

Representation describes the ability of a species to adapt to changing environmental conditions. We lack genetic and ecological diversity data to characterize representation for dwarf-flowered heartleaf. In the absence of species-specific genetic and ecological diversity information, we typically evaluate representation based on the extent and variability of habitat characteristics across the geographical range. However, the dwarf-flowered heartleaf has a very limited range, and after consulting with experts, we decided delineating representative units was not appropriate for this species.

Current Species Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events (such as a rare destructive natural event or episode involving many

populations). Redundancy for dwarf-flowered heartleaf is the total number and resilience of population segments and their distribution across the species range. As stated previously, there are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years, and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low); 2 (unknown). The populations are spread across the range, although a majority occur in North Carolina. Although, there appears to be adequate redundancy within the range of dwarf-flowered heartleaf, the species range is very small, making it potentially vulnerable to catastrophic events. Thus, we classify redundancy as inherently low for the species.

INFLUENCES ON VIABILITY

Hexastylis naniflora populations occur in rapidly growing urban areas with expanding suburbs of Charlotte, NC, to the east; Hickory, NC, to the north; and Greenville and Spartanburg, SC, to the south. At the time of listing, it was determined that the species was most threatened by habitat loss due to the conversion of land to residential, commercial, and industrial use in these areas. In addition to threats associated with residential, commercial, and industrial development, other documented threats include habitat loss from land conversion to agricultural use, timber harvest, hydrological alterations from the damming of ponds, impacts from grazing cattle, ORV damage, trampling from foot traffic, invasive species, highway or road improvements, and erosion or siltation (NCNHP 2016, Robinson and Padgett 2016). Climate change may exacerbate these risk factors through changes in temperature and precipitation.

Threats were assessed for populations monitored by NCNHP during 2012-2016 (Robinson and Padgett 2016), and EOs were reviewed for other documented threats to populations. Indirect or direct threats that were observed, inferred, or suspected to have an impact on populations were recorded and assigned a ranking based on their severity, scope, and immediacy from field observations. The rank for each threat factor determines the overall value for each threat observed at each population. No significant changes in threats within populations were noted from 2012-2016. Threats observed during these years included development, incompatible forestry practices, agriculture, trampling, invasive exotic species, sedimentation, erosion, and road construction.

Below, we summarize primary threats to the viability of dwarf-flowered heartleaf. Primary influences will be carried forward in our future projections in the next section.

Human Population Change

Increasing human populations drive development. With increases in population, there will be increasing conversion of open space to more impervious cover, with a subsequent increase in roads and other associated infrastructure. Increases in roads and impervious cover have the potential to lead to habitat loss and/or fragmentation, a primary risk factor for dwarf-flowered heartleaf. Tables 1-2 and Figures 1-2 show the estimated human population increases for North

Carolina and South Carolina counties within the range of the species. The most populous counties include Greenville and Spartanburg in South Carolina, and Catawba, Gaston and Iredell counties in North Carolina.

Table 1-Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

County	2018	2023	2028	2033	2037
Alexander	38609	39,244	39,686	39992	40169
Burke	90865	93,124	95,382	97644	99452
Caldwell	83919	86,723	88,689	91126	92870
Catawba	157424	159,799	162,175	164549	166447
Cleveland	98862	99,685	100,004	100128	100170
Gaston	221112	227,667	237,344	245276	252388
Iredell	179740	195,623	211,501	227383	240088
Lincoln	84494	91,034	96,865	103069	107858
Polk	21273	21,823	22,288	22681	22955
Rutherford	67880	68,154	68,283	68341	68368

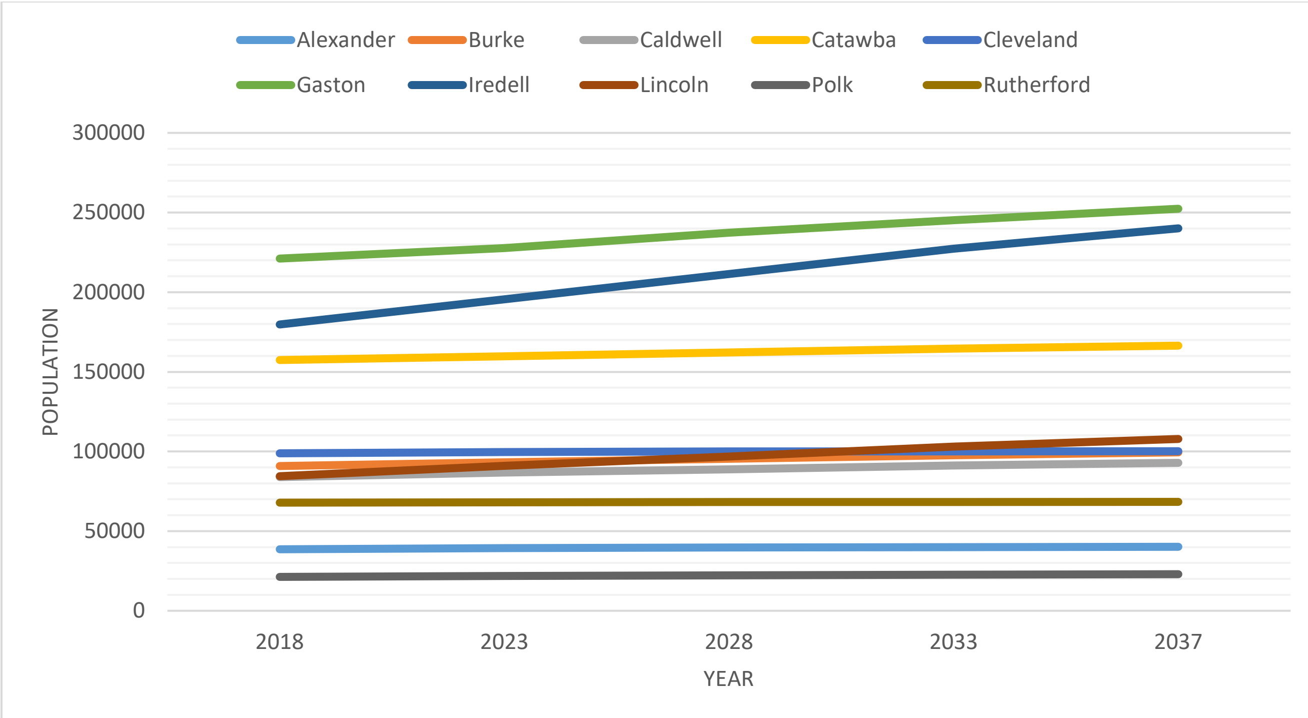


Figure 1- Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

Table 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
Greenville	492,890	517,740	542,290	567,010
Spartanburg	310,220	323,550	336,810	350,110

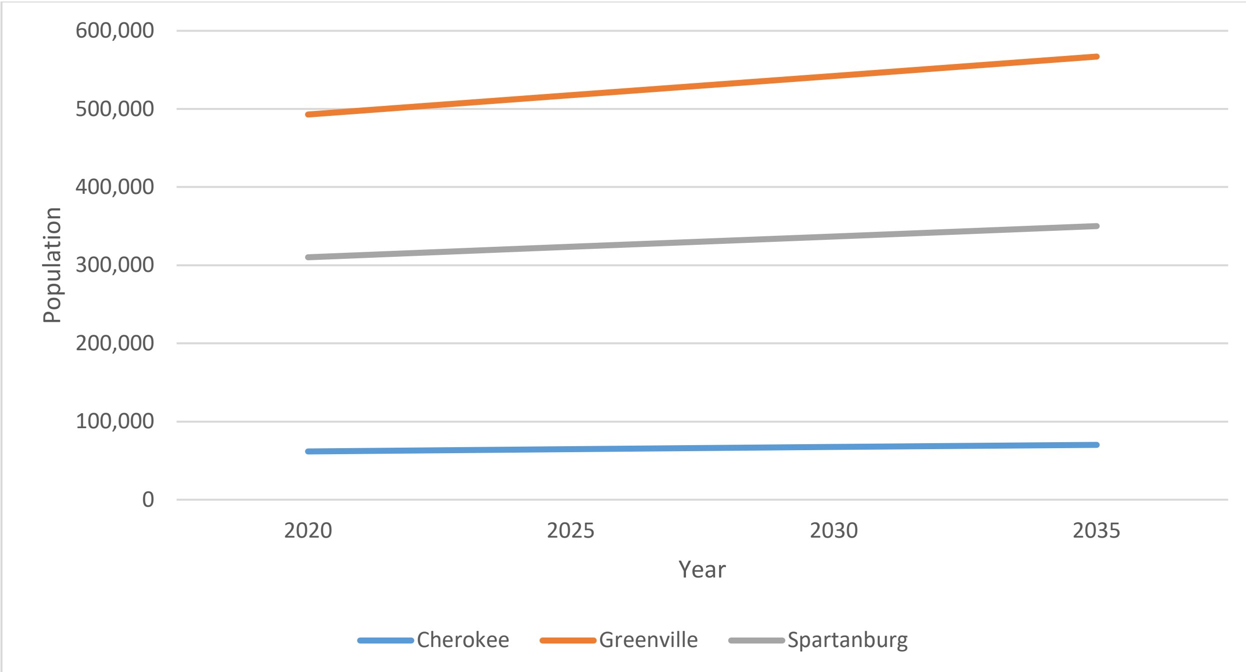


Figure 2- Human population projections for South Carolina counties within the range of dwarf-flowered heartleaf. *Source: U.S. Census Bureau, 2000 Census and 2007 Population Estimates. Population projections calculated by South Carolina Budget and Control Board, Office of Research and Statistics.*

Development

A large number of the known populations occur near expanding urban areas and are threatened by the residential, commercial, and industrial development associated with this growth. Populations occurring in more rural areas are threatened by habitat alteration or loss from land conversion to pasture or other agricultural uses, cattle grazing, intensive timber harvesting, residential construction, and construction of small ponds.

A 2011 review of existing NHP EOR data revealed that all or portions of 26 populations (24% of the total) had been directly or indirectly impacted through development projects or other causes such as trash disposal, expansion of residential lawns, cattle, or invasive exotics (NC NHP 2010; SCDNR 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

foreseeable within 42 of the 108 populations (corresponding to 39% of all known populations). Of these 42 populations, all or portions of 22 (50%) had been adversely impacted by activities requiring ESA Section 7 consultation with the USFWS. The fact that nearly 20% of all known populations had been subject to formal Section 7 consultation illustrates the threats faced by the species.

The most recurrent source of habitat destruction, and certainly the most common trigger for Section 7 consultations involving *H. naniflora* is road and bridge improvement projects. Ten of the 27 largest populations (containing more than 1,000 rosettes) have been the subject of Section 7 consultations between the USFWS and the NCDOT. Collectively, these projects have adversely impacted or are currently expected to impact some 22,135 rosettes. In most cases the Section 7 process has resulted in avoidance or minimization of adverse effects through relocation of plants and/or commitments of on-site protection to those plants remaining (post-construction) within NCDOT right-of-way (ROW).

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 consultations with the USFWS. Examples of these activities include the maintenance or expansion of hydroelectric and drinking water reservoirs, construction of an industrial development complex, and maintenance activities (in compliance with Federal Aviation Administration standards) at a regional airport. Collectively, these activities have involved the loss or relocation of several thousand rosette.

Blalock Reservoir in Spartanburg County, South Carolina was once estimated to contain the largest population of *H. naniflora*, with over 11,000 rosettes reported here in 1997 (JJ&G, 1998). This population was the subject of a section 7 consultation as a result of a proposal to raise the elevation of Blalock Reservoir, which provides water supply storage to Spartanburg County and the City of Spartanburg (USFWS, 2001). Approximately one-third of this population was directly threatened by inundation, and the Federal agency committed to the relocation of some 3,054 rosettes to remaining areas of occupied habitat around the reservoir. At the conclusion of formal section 7 consultation, the USFWS anticipated that as many as 6,619 rosettes (assuming

that all transplants survived) would be afforded protection through restrictive covenants placed on properties owned by the Spartanburg Water System (SWS) surrounding Blalock Reservoir. However, this population was last reported to contain a mere 1,400 rosettes (Newberry, 2006), and has twice since been impacted by encroachments from adjacent landowners (Newberry, 2009; Schneider, 2006, and JJ&G, 2006). Some of these apparent declines could be partially an artifact of incomplete survey effort, in that the exhaustive surveys which led to the 1997 estimate (of 11,000 rosettes) have never been repeated. However, it seems unlikely that plants occurring on privately owned shoreline not subject to restrictive covenants would be any more stable than those occurring on properties specifically protected and managed for the species (by SWS).

Invasive Species

Several of the known populations of dwarf-flowered heartleaf occur on steep ravine slopes which also support stands of mixed hardwoods with an understory of mountain laurel (*Kalmia latifolia*) or *Rhododendron spp*. These stands are often very dense and reduce the amount of light reaching the dwarf-flowered heartleaf plants growing below. Under these conditions the plants often show reduced vigor and reduced flower and fruit production. Careful, selective logging or natural tree fall and limited understory removal would open up these populations to more light. Additional light, if not accompanied by increased siltation from the intensive soil disturbances associated with forest clear-cutting, probably would benefit these populations (Gaddy 1981).

Invasive exotic plant species are rampantly spreading throughout riparian corridors and ravines across the range of this species. Invasive exotics such as English Ivy (*Hedera helix*), Chinese privet (*Ligustrum* spp.), Japanese honeysuckle (*Lonicera japonica*) and Japanese Nepal grass (*Microstegium vimineum*) are known to threaten several populations; however, the scope and magnitude of this threat has not been comprehensively assessed. This threat requires active management in order to be successfully abated. At present, the majority of protected populations are secured against habitat conversion, but lack designated managers with the technical expertise and available resources (funding and personnel) to address this threat.

Climate Change

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

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

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

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 (NCILT 2012, p.27; IPCC 2013, p.7):

- More frequent drought
- More extreme heat (resulting in increases in air and water temperatures, Figure 5-3)

- Increased heavy precipitation events (e.g., flooding)
- More intense storms (e.g., frequency of major hurricanes increases)
- Rising sea level and accompanying storm surge

In recent years, the Southeast has experienced moderate to severe droughts that many observers have implicated in population declines and poor transplant survivorship (NC NHP, 2010). A wildfire, presumably brought on or at least exacerbated by drought conditions, burned portions of one of the largest known populations in 2009 (Foothills Landfill in Caldwell County; Golder and Associates, 2009). Accelerated climate change is expected to increase the frequency and extent of drought conditions across the southeast (Karl, et al. 2009). The extent to which these climate changes will significantly affect populations of dwarf-flowered heartleaf is currently unknown.

Appendices 3a and 3b gives summary reports on historical and future predicted climate parameters from the USGS National Climate Change Viewer for both North Carolina and South Carolina. As discussed above, the trend for these States is as it is for the Southeast in general: more frequent drought, more extreme heat, and increased precipitation events. If these predictions hold true, dwarf-flowered heartleaf habitat would likely be impacted through increased evaporative rates and decreased soil moisture (Appendices 3a and 3b), increased potential for catastrophic wildfire events, as well as potential disruption of stream bank morphology through increased flooding events.

From:	Stephanie DeMay
To:	Marshall, Michael E; Mason, Suzanne; Amoroso, Jame; Matt Estep; tpbassette@ncdot.gov; Endries, Mark; Reid, Rebekah N; Becker, Drew N
Subject:	Re: HENA Drafts
Date:	Wednesday, February 28, 2018 11:26:18 PM
Attachments:	HENA CURRENT CONDITIONS 2.22.18 SMD.docx INFLUENCES ON VIABILITY HENA 2.22.18 SMD.docx
Importance:	High

A few comments/suggestions here and there, and a bit of a ramble about the nature of redundancy.

Nice work Mike!

From: Marshall, Michael <michael_marshall@fws.gov>
Sent: Thursday, February 22, 2018 8:19:12 AM
To: Mason, Suzanne; Amoroso, Jame; Matt Estep; tpbassette@ncdot.gov; Mark Endries; Rebekah; Drew Becker; Stephanie DeMay
Subject: HENA Drafts

Good morning Team!

Sorry for the delay, but here are the next two sections of the HENA SSA attached for your consideration and review, with appendices attached as well. These sections are Current Conditions and Influences on Viability. As you review and provide comments on these sections, we will be working on the Future Conditions section, which will be the final section of the SSA.

Please provide your edits and comments to these documents in track changes by **COB Friday March 2nd.**

Thanks you so much for your help and input on all of this. And, if at any time you have any questions, please feel free to contact me or Rebekah.

Take care and have a great weekend!

Mike

--
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

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 (NCNHP 2016a; NCNHP 2016b), the species consists of 113 populations distributed across 12 counties in North Carolina and South Carolina. Recent genetic research 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 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.

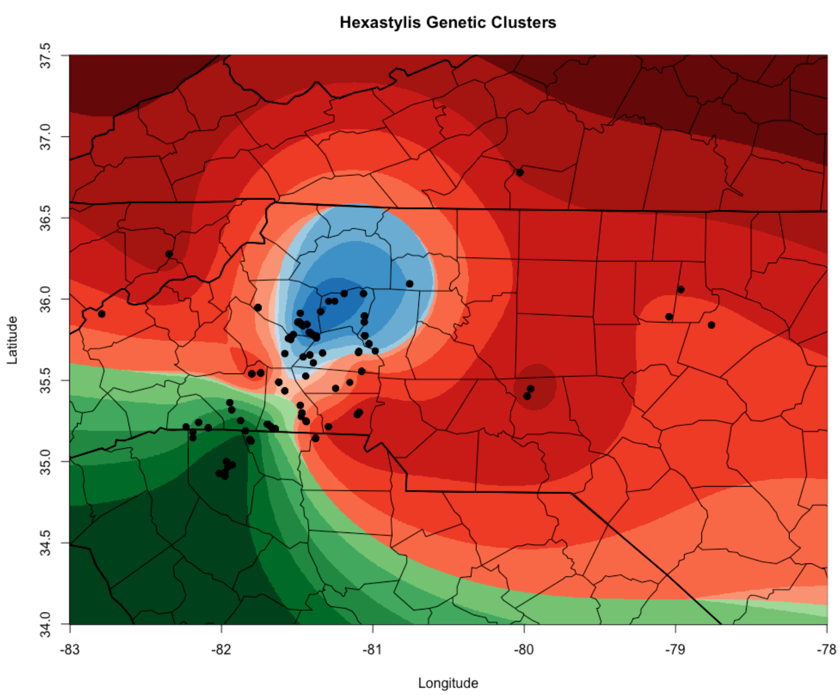


Figure 1-Recent genetic analyses detailing clustering of the genus Hexastylis. Green areas represent "true" *H. naniflora*; Blue represents a possible new species; Red represents other species in the genus (*H. minor, H. heterophylla*, etc.).

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 of years since the species was last observed at a given location (1964-2017), so although recent reports suggest the species consists of 113 populations, some of that data is fairly outdated. For the purposes of this SSA, we only used EO that were observed within the last 10 years (2007-2017). Based on that criteria, there are currently 68 populations distributed across the range of dwarf-flowered heartleaf, although this may be an underestimate as discussed in more detail in the habitat modelling section later.

To determine overall resilience for populations, we used EO viability ranks and expert opinion to bin population size classes into corresponding resilience categories. EO viability ranks for the species include excellent, good, fair, poor, extant, historical, and failed to find. The primary factor in determining these ranks is EO size (as quantified by number of clumps). Condition of habitat (vegetation community and structure) and landscape context (extent of suitable habitat and physical factors) are also incorporated secondarily. Appendix 1 shows the NCNHP EO rank specifications for dwarf-flowered heartleaf. The EO rank specifications suggest good-excellent viability for populations consisting of at least 500 individuals, given there is sufficient high quality habitat; fair viability for populations consisting of 100-500 individuals, depending on habitat conditions; poor viability for populations consisting of less than 100 individuals. Recent

reports (NCNHP 2016a; NCNHP 2016b) focus monitoring studies on populations with greater than 1,000 individuals, populations that are assumed to be very viable. Because we do not have habitat level information for every population we assessed, we synthesized all of the 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, and moderate-high probability of extirpation for 20-30 years at or above the current population size.

Occupancy and Abundance

There are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years (Table 1), and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low). Table 2 shows the contribution of each resilience category as follows: 40% (very high); 7% (high); 30% (moderate); 22% (low). When looking at cumulative percentages of resilience, it is interesting to note that 78% of all of the populations are classified as moderate to very high resilience (Table 2).

Commented [S1]: 68 mentioned above.

Commented [S2]: Philosophical question similar to RCW conversations- is moderate good or bad? Adding its percentage to high and very high here looks like you're saying moderate is good. Maybe it is. If it's not that good though, I would suggest not lumping it into a cumulative percentage with high and very high.

Table 1--Current populations of dwarf-leafed heartflower and associated resilience across the species range.

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

Cowpens NBF - Site 1	South Carolina	Cherokee	2016	>1000	very High
Cliffside Steam Station	North Carolina	Clev/Ruth	2016	>1000	very high
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	>1000	very high
Broad River: Brushy Creek	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Kings Mountain Res	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Tributaries N and S of SR 2047	North Carolina	Cleveland	2012	>1000	very high
Rhyne Conservation Preserve	North Carolina	Lincoln	2016	>1000	very high
Mill Creek Forest and Seep	North Carolina	Polk	2016	>1000	very high
New Hope Springhead Swamp	North Carolina	Polk	2016	>1000	very high
Big Horse Creek Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Broad River: Floyds Creek	North Carolina	Rutherford	2016	>1000	very high
Davenport Road/Mountain View Rare Plant Site	North Carolina	Rutherford	2016	>1000	very high
Facebook Site	North Carolina	Rutherford	2016	>1000	very high
Floyds Creek Tributray Rare Plant Site	North Carolina	Rutherford	2012	>1000	very high
New Bethel Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Richardson Creek trib above Toms Lake	North Carolina	Rutherford	2016	>1000	very high
DNR Peters Creek Heritage Preserve	South Carolina	Spartanburg	2016	>1000	very High
Taylor Blalock Res	South Carolina	Spartanburg	2016	>1000	very High
Little Gunpowder Creek Rare Plant Site 1	North Carolina	Caldwell	2015	500-1000	high
Little Gunpowder Creek Rare Plant Site 2	North Carolina	Caldwell	2015	500-1000	high
Northern Catawba County	North Carolina	Catawba	2017	500-1000	high
Rock Barn Solar Farm	North Carolina	Catawba	2010-2011	500-1000	high
Buffalo Creek Rare Plant Site	North Carolina	Cleveland	2012	500-1000	high
Third Creek Rare Plant Site	North Carolina	Alexander	2010	100-500	moderate
Hickory Area	North Carolina	Burk/Cata/Cald	2016	100-500	moderate
Burke County - Drowning Creek UT	North Carolina	Burke	2017	100-500	moderate
Simms Hill/Little River Uplands	North Carolina	Burke	2015	100-500	moderate
Smith Cliff/Henry Fork River	North Carolina	Burke	2015	100-500	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork Catawba River Jacobs Fork and Camp Creek	North Carolina	Catawba	2016	100-500	moderate
NCDOT TIP R-2824	North Carolina	Catawba	2015	100-500	moderate
South Fork Catawba River, Henry Fork	North Carolina	Catawba	2007	100-500	moderate
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	100-500	moderate
Brushy Creek Headwaters	North Carolina	Cleveland	2014	100-500	moderate
First Broad River: Crooked Run Creek	North Carolina	Cleveland	2010	100-500	moderate
No Business Creek, Boyd Tract	North Carolina	Cleveland	2007	100-500	moderate
West Shelby Mesic Slope	North Carolina	Cleveland	2016	100-500	moderate
UT of Kings Mountain Res	North Carolina	Gaston	2012	100-500	moderate
Buffalo Shoals Creek	North Carolina	Iredell	2014	100-500	moderate
Cat Square Heartleaf Forest	North Carolina	Lincoln	2012	100-500	moderate
Collinsville (Hughes) Creek Slopes	North Carolina	Polk	2016	100-500	moderate
Fox Knoll Farm	North Carolina	Polk	2016	100-500	moderate
Forest City: Adj to Isothermal CC	North Carolina	Rutherford	2010	100-500	moderate
Jonas Road Rare Plant Site	North Carolina	Rutherford	2014	100-500	moderate
NCDOT TIP R-3603A	North Carolina	Alexander	2017	<100	low
South Mountains Pleasant Grove Uplands	North Carolina	Burke	2016	<100	low

Gunpowder Creek	North Carolina	Caldwell	2012	<100	low
Killian Crossroads	North Carolina	Catawba	2010	<100	low
Pott Creek	North Carolina	Catawba	2012	<100	low
Beaverdam Crk at First Broad River	North Carolina	Cleveland	2011	<100	low
Buffalo Creek: Potts Creek	North Carolina	Cleveland	2012	<100	low
Buffalo Creek: Ravine	North Carolina	Cleveland	2007	<100	low
Hickory Creek - UT (Shelby High School)	North Carolina	Cleveland	2016	<100	low
Boulder Creek Subdivision - Jordan Road	South Carolina	Greenville	2016	<100	low
Gateway Elementary School	South Carolina	Greenville	2017	<100	low
Fanjoy Road Site	North Carolina	Iredell	2015	<100	low
Levan Family Farm	North Carolina	Iredell	2013	<100	low
Lincoln County, SR-1314	North Carolina	Lincoln	2014	<100	low
Northeast Lincolnton: UT Walker Branch	North Carolina	Lincoln	2009	<100	low

Table 2--Population resilience categories by county for dwarf-flowered heartleaf.

County	Very High	High	Moderate	Low	Totals
Alexander	1		1	1	3
Burk/Cata/Cald			1		1
Burke	2		3	1	6
Caldwell	2	2		1	5
Catawba	4	2	3	2	11
Cherokee	1				1
Clev/Ruth	1				1
Cleveland	4	1	5	4	14
Gaston			1		1
Greenville				2	2
Iredell			1	2	3
Lincoln	1		1	2	4
Polk	2		2		4
Rutherford	7		2		9
Spartanburg	2				2
Totals	**27**	**5**	**20**	**15**	**67**
% of total	*40*	*7*	*30*	*22*	*100*
Cumulative %	*40*	*48*	*78*	*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 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 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: NCNHP).

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	Rhyne 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
	NCNHP	Broad River: Henson's Creek, Brice, & Sandy Mush Outcrop (EO 099)	106,940	83.39
	NCNHP	Broad River: Cleghorn Creek, US 221 (EO 176)	6,750	7.24
	NCNHP	Cowpens National Battlefield (SC EO 016, 017, 018)	2,823	6.05
	NCNHP	Peters Creek Preserve (SC EO 011)	3,306	8.98
	NCNHP	Blalock Reservoir (SC EO 007, 031)	3,505	7.59
Decreasing	NCNHP	Second Broad River (Forest City Industrial Complex) (EO 154)	2,576	4.74
	NCNHP	South Fork Catawba River: Jacob Fork, Camp Creek (EO 158)	123	0.09

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

A previous habitat suitability study attempted to quantify the habitat requirements for dwarf-flowered heartleaf. A model was created to predict habitat suitability, and based on the model results, the strongest habitat correlations were slope, aspect, soil type, elevation, and land use (Wagner 2015). With this model in mind, 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 2.

Source Data and Model Variables

Fifty three, 10-digit hydrologic units (HUC) comprise the analysis extent. In North Carolina, it includes all 10-digit HUC that fall within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*. In South Carolina, we also included all 10-digit HUC that fell within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*, 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. These data were in polygon format and digitized at a scale that accurately identified the boundaries of the individual population areas. 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 in the last 10 years (since 2007). 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.

Commented [S3]: Either add software version/citation stuff up here with the first mention of Maxent, or here use a more general term like "the habitat model" and save the details for the next paragraph where they already are.

Model Development

We used Maxent software (version 3.4.1) for species habitat modeling (Philips 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, SSURGO drainage class, SSURGO hydrologic group, aspect 9-class, aspect 5-class, slope, and maximum annual temperature.

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 2 shows the model output. The minimum cutoff value (to determine if an area is considered potential habitat for a species) of 0.406 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 predictions to focus on the typical habitat conditions for this species. The total area ranked greater than 0.406 in the Maxent model was just 6.39% of the total analysis area (Table 4).

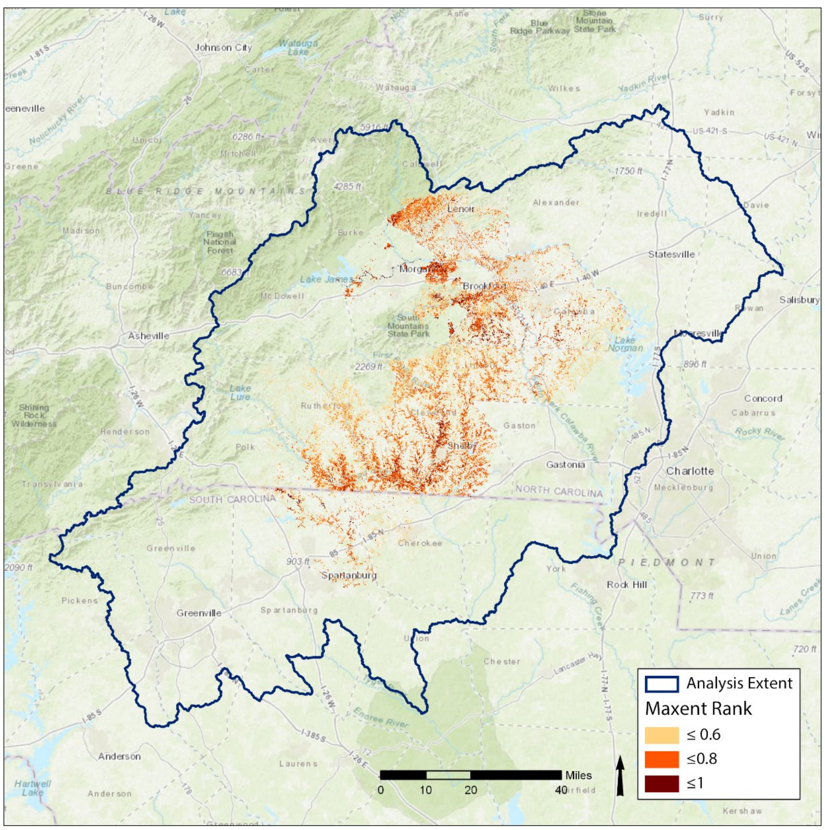


Figure 2-Maxent model output map

Table 4-Area estimates of the Maxent model

Maxent Score	Acres	Square Miles	Percent of Total
0.406 and greater	321,262.37	501.97	6.39%
0.6 and greater	146,712.65	229.24	2.92%
0.8 and greater	22,677.96	35.43	0.45%

The average area-under-curve (AUC) score for the replicate Maxent model is 0.849. The AUC is calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1 and may be interpreted as a single test statistic that assesses model performance, indicating the ability of the model to correctly classify the occurrence data used. The model performed well in its predictions, with a mean AUC of 0.849 (AUC value of 0.5 is no better than random; AUC<0.5 is worse than random; AUC>0.5 is greater predictive power than random; Baldwin 2009).

The Maxent output supplies estimates of the relative contributions of the environmental variables to the Maxent model (Table 5). SSURGO mukey is the top contributing variable. One hundred and thirty-five individual soil types are present within the polygon boundaries of the *Hexastylis naniflora* element occurrences. Many of these individual soil types are part of soil complexes and are separated by things such as percent slope, erosion, how stony/rocky, and amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25 to 60 percent slopes, very stony (12.9% of total). However, collectively the Meadowfield soils only comprised 13.5% of all soils). The individual Pacolet soil types were very common and collectively comprise 36% of all soil types present. Woolwine soils were also collectively common, comprising 10% of all soils present.

Commented [S4]: Unclear to the untrained reader why these 4 soil types are called out. Are these just the most common soils in the entire extent of the analysis area? Are these associated with HENA habitat?

The minimum annual average temperature range in the analysis extent is 39 – 51 degrees Fahrenheit. The majority of the *Hexastylis naniflora* element occurrences (92%) 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 (81%) are found in the 47 – 49 inches per year range.

Piedmont forested landcover habitats dominate the land area of the element occurrences. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier (52%), Southern Piedmont Mesic Forest (10%), Southern Piedmont Small Floodplain and Riparian Forest (3.6%), and Southern Piedmont Dry Oak-Pine Forest – Loblolly Pine Modifier (2.3%) collectively comprise 72% of the element occurrences area. Unfortunately, non-native habitats are also present. Evergreen Plantation or Managed Pine (8%), Harvested Forest – Grass/Forb Regeneration (7%), Developed, Open Space (5%), Pasture/Hay (2.5%) 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 landcover classes, but each at small percentages.

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The landcover majority classification scheme reduces the total number of landcover classes present in the analysis extent from 23 to 12. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landcover class (56%). 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 landcover area representation in the landcover majority layer suggests that many *Hexastylis naniflora* population areas are situated in areas impacted by disturbed landcover. This is likely due to urban encroachment and increasing fragmentation of habitats.

The landcover Hexastylis grouping reveals the amount of disturbance present in Hexastylis population areas. Landcover classes grouped as disturbed compris 26% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, hardwood forest 11%, and riparian 3.6%. Open water, evergreen and barren landcover groupings are all at less than 1% each.

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Geomorphons revealed that the majority of *Hexastylis naniflora* element occurrence areas are situated in concave landforms. Geomorphon categories hollow (15%), valley (35%), and depression (17%) collectively comprise 67% of all *Hexastylis naniflora* population areas. Flat landforms comprise 22.5% of the area and convex landforms the remaining 10.5%.

Within the analysis extent, the range of elevation present is 335 – 5,265 feet. For *Hexastylis naniflora*, the prime elevation range is from 666 – 896 feet (54% of total element occurrence area). A lesser elevation range is present from 935 – 1,165 (35% of total element occurrence area).

Table 5-Percent contribution of the environmental variables

Environmental Variable	Percent Contribution
SSURGO mukey	23.3%
Minimum Annual Temperature	20.7%
Average Annual Precipitation	14.6%
Landcover	13%
Landcover Majority	9.5%
Landcover Hexastylis Grouping	7.3%
Geomorphons	6.4%
Elevation	5.2%

We performed an Analysis of Variance test to investigate the relationship between Maxent scores and current resilience of populations (Table 6). There are significant differences in the average Maxent scores between the four resilience categories ($p = 0.01$) and the mean Maxent score increases as population resilience increases for low to very high. It appears the model gives us some predictive ability regarding habitat quality, where higher Maxent scores, on average, result in higher population resilience.

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Table 6-Results of the ANOVA investigating relationships between Maxent scores and current resilience groups for dwarf-flowered heartleaf.

Groups	*Count*	*Sum*	*Average*	*Variance*
low	13	5.240363	0.403105	0.124194
moderate	20	8.851696	0.442585	0.040139
high	4	2.292114	0.573028	0.039821
very high	27	16.66603	0.61726	0.020717

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.563333	3	0.187778	3.870253	0.01346	2.758078
Within Groups	2.911089	60	0.048518			
Total	3.474421	63				

Current Species Representation

Representation describes the ability of a species to adapt to changing environmental conditions. We lack genetic and ecological diversity data to characterize representation for dwarf-flowered heartleaf. In the absence of species-specific genetic and ecological diversity information, we typically evaluate representation based on the extent and variability of habitat characteristics across the geographical range. However, the dwarf-flowered heartleaf has a very limited range, and after consulting with experts, we decided delineating representative units was not appropriate for this species.

Current Species Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events (such as a rare destructive natural event or episode involving many

populations). Redundancy for dwarf-flowered heartleaf is the total number and resilience of population segments and their distribution across the species range. As stated previously, there are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years, and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low); 2 (unknown). The populations are spread across the range, although a majority occur in North Carolina. Although, there appears to be adequate redundancy within the range of dwarf-flowered heartleaf, the species range is very small, making it potentially vulnerable to catastrophic events. Thus, we classify redundancy as inherently low for the species.

Commented [S7]: Or 68?

Commented [S8]: This is such a subjective thing, I was struggling with this for the aster too. It really depends on the scale of the catastrophic event populations need to bounce back from (broad-scale drought, medium scale disease outbreak, local catastrophic wildfire or flood or manmade disturbance or something). I would guess that there aren't a lot of catastrophic events that would devastate the entire range, and 67 populations, 32 of which are highly or very highly resilient, seems like some pretty great redundancy to me given the limited range. Given the subjectivity and dependence on what the catastrophe is, I'm leaning towards giving more explanation to those things. Like explicitly say if we're talking about a broad scale climate thing like drought, redundancy is definitely low, but if we're talking about other catastrophes, that changes. And/or maybe some discussion of what catastrophes are likely to impact populations and what their scale is. For example, maybe drought is the only catastrophe that might impact populations, and there is only that one important scale to think about. But maybe there are multiple catastrophes that pop up. Some of the threats listed in the influences on viability section could count as more local catastrophes (e.g. timber harvest, hydrological alterations from the damming of ponds, impacts from grazing cattle, ORV damage, trampling from foot traffic, invasive species, highway or road improvements, and erosion or siltation). A lot of rambling, but things I've been thinking about. There's not a ton of guidance that I've seen about how to approach redundancy and it seems so subjective and scale-dependent that I want to make sure I'm super clear about where I'm coming from.

INFLUENCES ON VIABILITY

Hexastylis naniflora populations occur in rapidly growing urban areas with expanding suburbs of Charlotte, NC, to the east; Hickory, NC, to the north; and Greenville and Spartanburg, SC, to the south. At the time of listing, it was determined that the species was most threatened by habitat loss due to the conversion of land to residential, commercial, and industrial use in these areas. In addition to threats associated with residential, commercial, and industrial development, other documented threats include habitat loss from land conversion to agricultural use, timber harvest, hydrological alterations from the damming of ponds, impacts from grazing cattle, ORV damage, trampling from foot traffic, invasive species, highway or road improvements, and erosion or siltation (NCNHP 2016, Robinson and Padgett 2016). Climate change may exacerbate these risk factors through changes in temperature and precipitation.

Threats were assessed for populations monitored by NCNHP during 2012-2016 (Robinson and Padgett 2016), and EOs were reviewed for other documented threats to populations. Indirect or direct threats that were observed, inferred, or suspected to have an impact on populations were recorded and assigned a ranking based on their severity, scope, and immediacy from field observations. The rank for each threat factor determines the overall value for each threat observed at each population. No significant changes in threats within populations were noted from 2012-2016. Threats observed during these years included development, incompatible forestry practices, agriculture, trampling, invasive exotic species, sedimentation, erosion, and road construction.

Below, we summarize primary threats to the viability of dwarf-flowered heartleaf. Primary influences will be carried forward in our future projections in the next section.

Human Population Change

Increasing human populations drive development. With increases in population, there will be increasing conversion of open space to more impervious cover, with a subsequent increase in roads and other associated infrastructure. Increases in roads and impervious cover have the potential to lead to habitat loss and/or fragmentation, a primary risk factor for dwarf-flowered heartleaf. Tables 1-2 and Figures 1-2 show the estimated human population increases for North

Commented [S1]: Consider using only tables or only figures, since they are showing the same information, just in different ways. Maybe show just the figures because they're easier to interpret, but mention some interesting ones in writing, like Iridell Co increasing from XX big number to XXX mega bigger number by 2037.

Carolina and South Carolina counties within the range of the species. The most populous counties include Greenville and Spartanburg in South Carolina, and Catawba, Gaston and Iredell counties in North Carolina.

Table 1-Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

County	2018	2023	2028	2033	2037
Alexander	38609	39,244	39,686	39992	40169
Burke	90865	93,124	95,382	97644	99452
Caldwell	83919	86,723	88,689	91126	92870
Catawba	157424	159,799	162,175	164549	166447
Cleveland	98862	99,685	100,004	100128	100170
Gaston	221112	227,667	237,344	245276	252388
Iredell	179740	195,623	211,501	227383	240088
Lincoln	84494	91,034	96,865	103069	107858
Polk	21273	21,823	22,288	22681	22955
Rutherford	67880	68,154	68,283	68341	68368

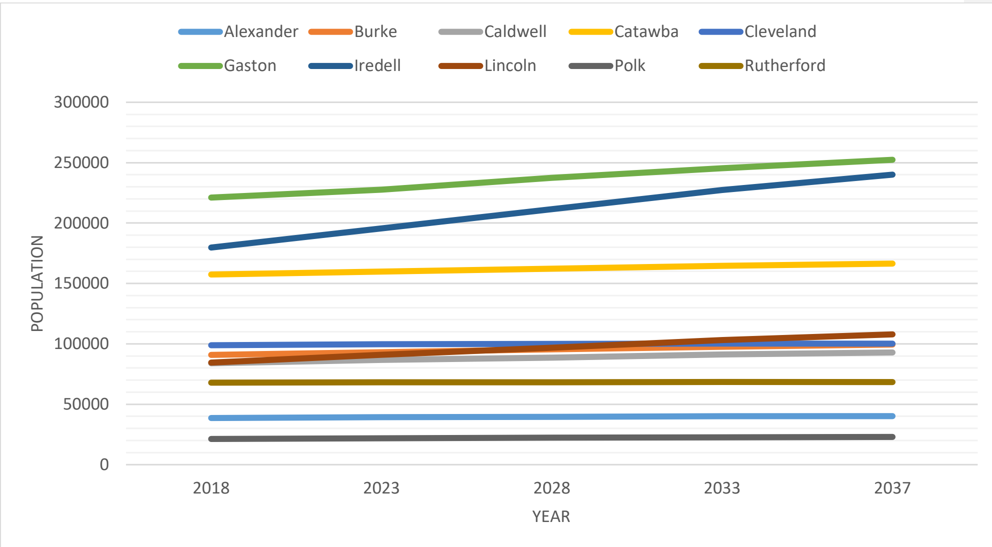

Figure 1- Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

Table 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
Greenville	492,890	517,740	542,290	567,010
Spartanburg	310,220	323,550	336,810	350,110

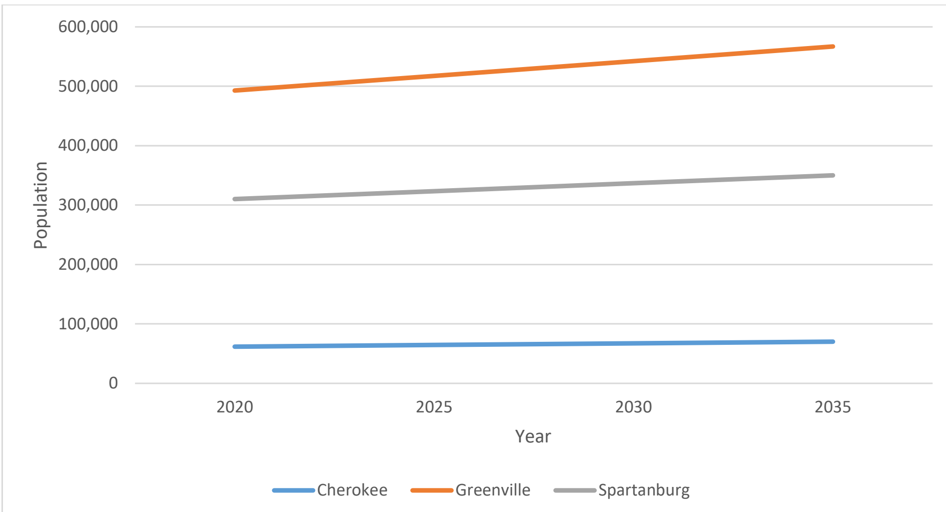

Figure 2- Human population projections for South Carolina counties within the range of dwarf-flowered heartleaf. *Source: U.S. Census Bureau, 2000 Census and 2007 Population Estimates. Population projections calculated by South Carolina Budget and Control Board, Office of Research and Statistics.*

Development

A large number of the known populations occur near expanding urban areas and are threatened by the residential, commercial, and industrial development associated with this growth. Populations occurring in more rural areas are threatened by habitat alteration or loss from land conversion to pasture or other agricultural uses, cattle grazing, intensive timber harvesting, residential construction, and construction of small ponds.

A 2011 review of existing NHP EOR data revealed that all or portions of 26 populations (24% of the total) had been directly or indirectly impacted through development projects or other causes such as trash disposal, expansion of residential lawns, cattle, or invasive exotics (NC NHP 2010; SCDNR 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

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foreseeable within 42 of the 108 populations (corresponding to 39% of all known populations). Of these 42 populations, all or portions of 22 (50%) had been adversely impacted by activities requiring ESA Section 7 consultation with the USFWS. The fact that nearly 20% of all known populations had been subject to formal Section 7 consultation illustrates the threats faced by the species.

The most recurrent source of habitat destruction, and certainly the most common trigger for Section 7 consultations involving *H. naniflora* is road and bridge improvement projects. Ten of the 27 largest populations (containing more than 1,000 rosettes) have been the subject of Section 7 consultations between the USFWS and the NCDOT. Collectively, these projects have adversely impacted or are currently expected to impact some 22,135 rosettes. In most cases the Section 7 process has resulted in avoidance or minimization of adverse effects through relocation of plants and/or commitments of on-site protection to those plants remaining (post-construction) within NCDOT right-of-way (ROW).

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 consultations with the USFWS. Examples of these activities include the maintenance or expansion of hydroelectric and drinking water reservoirs, construction of an industrial development complex, and maintenance activities (in compliance with Federal Aviation Administration standards) at a regional airport. Collectively, these activities have involved the loss or relocation of several thousand rosette.

Blalock Reservoir in Spartanburg County, South Carolina was once estimated to contain the largest population of *H. naniflora*, with over 11,000 rosettes reported here in 1997 (JJ&G, 1998). This population was the subject of a section 7 consultation as a result of a proposal to raise the elevation of Blalock Reservoir, which provides water supply storage to Spartanburg County and the City of Spartanburg (USFWS, 2001). Approximately one-third of this population was directly threatened by inundation, and the Federal agency committed to the relocation of some 3,054 rosettes to remaining areas of occupied habitat around the reservoir. At the conclusion of formal section 7 consultation, the USFWS anticipated that as many as 6,619 rosettes (assuming

that all transplants survived) would be afforded protection through restrictive covenants placed on properties owned by the Spartanburg Water System (SWS) surrounding Blalock Reservoir. However, this population was last reported to contain a mere 1,400 rosettes (Newberry, 2006), and has twice since been impacted by encroachments from adjacent landowners (Newberry, 2009; Schneider, 2006, and JJ&G, 2006). Some of these apparent declines could be partially an artifact of incomplete survey effort, in that the exhaustive surveys which led to the 1997 estimate (of 11,000 rosettes) have never been repeated. However, it seems unlikely that plants occurring on privately owned shoreline not subject to restrictive covenants would be any more stable than those occurring on properties specifically protected and managed for the species (by SWS).

Invasive Species

Several of the known populations of dwarf-flowered heartleaf occur on steep ravine slopes which also support stands of mixed hardwoods with an understory of mountain laurel (*Kalmia latifolia*) or *Rhododendron spp*. These stands are often very dense and reduce the amount of light reaching the dwarf-flowered heartleaf plants growing below. Under these conditions the plants often show reduced vigor and reduced flower and fruit production. Careful, selective logging or natural tree fall and limited understory removal would open up these populations to more light. Additional light, if not accompanied by increased siltation from the intensive soil disturbances associated with forest clear-cutting, probably would benefit these populations (Gaddy 1981).

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I hope not, I <3 mountain laurel

Invasive exotic plant species are rampantly spreading throughout riparian corridors and ravines across the range of this species. Invasive exotics such as English Ivy (*Hedera helix*), Chinese privet (*Ligustrum* spp.), Japanese honeysuckle (*Lonicera japonica*) and Japanese Nepal grass (*Microstegium vimineum*) are known to threaten several populations; however, the scope and magnitude of this threat has not been comprehensively assessed. This threat requires active management in order to be successfully abated. At present, the majority of protected populations are secured against habitat conversion, but lack designated managers with the technical expertise and available resources (funding and personnel) to address this threat.

Climate Change

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

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

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

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 (NCILT 2012, p.27; IPCC 2013, p.7):

- More frequent drought
- More extreme heat (resulting in increases in air and water temperatures, Figure 5-3)

- Increased heavy precipitation events (e.g., flooding)
- More intense storms (e.g., frequency of major hurricanes increases)
- Rising sea level and accompanying storm surge

In recent years, the Southeast has experienced moderate to severe droughts that many observers have implicated in population declines and poor transplant survivorship (NC NHP, 2010). A wildfire, presumably brought on or at least exacerbated by drought conditions, burned portions of one of the largest known populations in 2009 (Foothills Landfill in Caldwell County; Golder and Associates, 2009). Accelerated climate change is expected to increase the frequency and extent of drought conditions across the southeast (Karl, et al. 2009). The extent to which these climate changes will significantly affect populations of dwarf-flowered heartleaf is currently unknown.

Appendices 3a and 3b gives summary reports on historical and future predicted climate parameters from the USGS National Climate Change Viewer for both North Carolina and South Carolina. As discussed above, the trend for these States is as it is for the Southeast in general: more frequent drought, more extreme heat, and increased precipitation events. If these predictions hold true, dwarf-flowered heartleaf habitat would likely be impacted through increased evaporative rates and decreased soil moisture (Appendices 3a and 3b), increased potential for catastrophic wildfire events, as well as potential disruption of stream bank morphology through increased flooding events.

From:	Reid, Rebekah N
To:	Marshall, Michael E
Subject:	Re: HENA Drafts
Date:	Thursday, March 1, 2018 3:17:59 PM
Attachments:	HENA_CURRENT CONDITIONS 2.22.18 RNR comments.docx INFLUENCES ON VIABILITY_HENA 2.22.18 RNR Comment.docx
Importance:	High

Hi Mike,

A few more comments.

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

On Thu, Feb 22, 2018 at 9:19 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:

> Good morning Team!
>
> Sorry for the delay, but here are the next two sections of the HENA SSA attached for your consideration and review, with appendices attached as well. These sections are Current Conditions and Influences on Viability. As you review and provide comments on these sections, we will be working on the Future Conditions section, which will be the final section of the SSA.
>
> Please provide your edits and comments to these documents in track changes by **COB Friday March 2nd.**
>
> Thanks you so much for your help and input on all of this. And, if at any time you have any questions, please feel free to contact me or Rebekah.
>
> Take care and have a great weekend!
>
> Mike
> --
> 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

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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 (NCNHP 2016a; NCNHP 2016b), the species consists of 113 populations distributed across 12 counties in North Carolina and South Carolina. Recent genetic research 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 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.

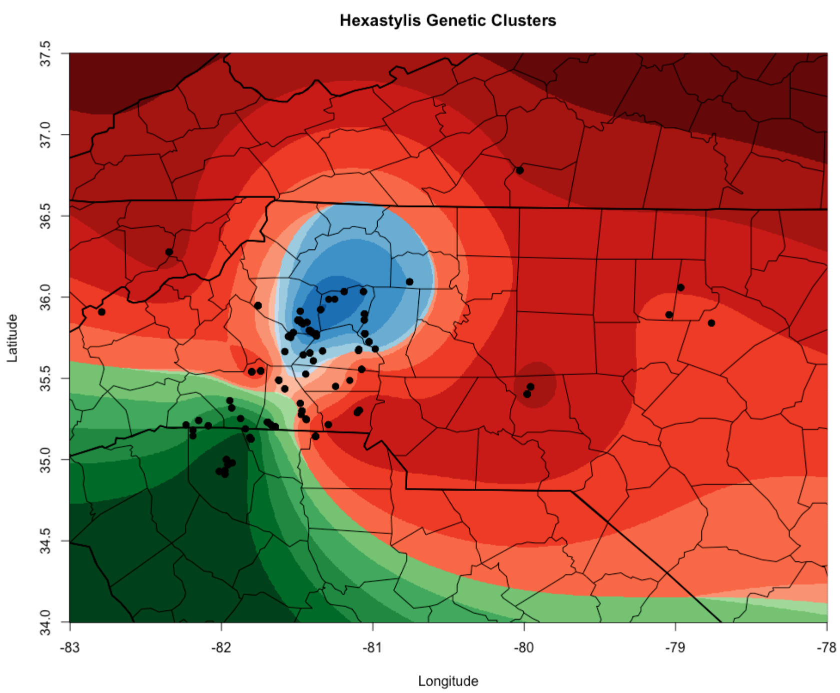

Figure 1-Recent genetic analyses detailing clustering of the genus Hexastylis. Green areas represent "true" *H. naniflora*; Blue represents a possible new species; Red represents other species in the genus (*H. minor, H. heterophylla*, etc.).

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 of years since the species was last observed at a given location (1964-2017), so although recent reports suggest the species consists of 113 populations, some of that data is fairly outdated. For the purposes of this SSA, we only used EO that were observed within the last 10 years (2007-2017). Based on that criteria, there are currently 68 populations distributed across the range of dwarf-flowered heartleaf, although this may be an underestimate as discussed in more detail in the habitat modelling section later.

To determine overall resilience for populations, we used EO viability ranks and expert opinion to bin population size classes into corresponding resilience categories. EO viability ranks for the species include excellent, good, fair, poor, extant, historical, and failed to find. The primary factor in determining these ranks is EO size (as quantified by number of clumps). Condition of habitat (vegetation community and structure) and landscape context (extent of suitable habitat and physical factors) are also incorporated secondarily. Appendix 1 shows the NCNHP EO rank specifications for dwarf-flowered heartleaf. The EO rank specifications suggest good-excellent viability for populations consisting of at least 500 individuals, given there is sufficient high quality habitat; fair viability for populations consisting of 100-500 individuals, depending on habitat conditions; poor viability for populations consisting of less than 100 individuals. Recent

reports (NCNHP 2016a; NCNHP 2016b) focus monitoring studies on populations with greater than 1,000 individuals, populations that are assumed to be very viable. Because we do not have habitat level information for every population we assessed, we synthesized all of the 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, and moderate-high probability of extirpation for 20-30 years at or above the current population size.

Occupancy and Abundance

There are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years (Table 1), and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low). Table 2 shows the contribution of each resilience category as follows: 40% (very high); 7% (high); 30% (moderate); 22% (low). When looking at cumulative percentages of resilience, it is interesting to note that 78% of all of the populations are classified as moderate to very high resilience (Table 2).

Commented [RNR1]: 68 is mentioned above.

Table 1--Current populations of dwarf-leafed heartflower and associated resilience across the species range.

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

Cowpens NBF - Site 1	South Carolina	Cherokee	2016	>1000	very High
Cliffside Steam Station	North Carolina	Clev/Ruth	2016	>1000	very high
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	>1000	very high
Broad River: Brushy Creek	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Kings Mountain Res	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Tributaries N and S of SR 2047	North Carolina	Cleveland	2012	>1000	very high
Rhyne Conservation Preserve	North Carolina	Lincoln	2016	>1000	very high
Mill Creek Forest and Seep	North Carolina	Polk	2016	>1000	very high
New Hope Springhead Swamp	North Carolina	Polk	2016	>1000	very high
Big Horse Creek Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Broad River: Floyds Creek	North Carolina	Rutherford	2016	>1000	very high
Davenport Road/Mountain View Rare Plant Site	North Carolina	Rutherford	2016	>1000	very high
Facebook Site	North Carolina	Rutherford	2016	>1000	very high
Floyds Creek Tributray Rare Plant Site	North Carolina	Rutherford	2012	>1000	very high
New Bethel Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Richardson Creek trib above Toms Lake	North Carolina	Rutherford	2016	>1000	very high
DNR Peters Creek Heritage Preserve	South Carolina	Spartanburg	2016	>1000	very High
Taylor Blalock Res	South Carolina	Spartanburg	2016	>1000	very High
Little Gunpowder Creek Rare Plant Site 1	North Carolina	Caldwell	2015	500-1000	high
Little Gunpowder Creek Rare Plant Site 2	North Carolina	Caldwell	2015	500-1000	high
Northern Catawba County	North Carolina	Catawba	2017	500-1000	high
Rock Barn Solar Farm	North Carolina	Catawba	2010-2011	500-1000	high
Buffalo Creek Rare Plant Site	North Carolina	Cleveland	2012	500-1000	high
Third Creek Rare Plant Site	North Carolina	Alexander	2010	100-500	moderate
Hickory Area	North Carolina	Burk/Cata/Cald	2016	100-500	moderate
Burke County - Drowning Creek UT	North Carolina	Burke	2017	100-500	moderate
Simms Hill/Little River Uplands	North Carolina	Burke	2015	100-500	moderate
Smith Cliff/Henry Fork River	North Carolina	Burke	2015	100-500	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork Catawba River Jacobs Fork and Camp Creek	North Carolina	Catawba	2016	100-500	moderate
NCDOT TIP R-2824	North Carolina	Catawba	2015	100-500	moderate
South Fork Catawba River, Henry Fork	North Carolina	Catawba	2007	100-500	moderate
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	100-500	moderate
Brushy Creek Headwaters	North Carolina	Cleveland	2014	100-500	moderate
First Broad River: Crooked Run Creek	North Carolina	Cleveland	2010	100-500	moderate
No Business Creek, Boyd Tract	North Carolina	Cleveland	2007	100-500	moderate
West Shelby Mesic Slope	North Carolina	Cleveland	2016	100-500	moderate
UT of Kings Mountain Res	North Carolina	Gaston	2012	100-500	moderate
Buffalo Shoals Creek	North Carolina	Iredell	2014	100-500	moderate
Cat Square Heartleaf Forest	North Carolina	Lincoln	2012	100-500	moderate
Collinsville (Hughes) Creek Slopes	North Carolina	Polk	2016	100-500	moderate
Fox Knoll Farm	North Carolina	Polk	2016	100-500	moderate
Forest City: Adj to Isothermal CC	North Carolina	Rutherford	2010	100-500	moderate
Jonas Road Rare Plant Site	North Carolina	Rutherford	2014	100-500	moderate
NCDOT TIP R-3603A	North Carolina	Alexander	2017	<100	low
South Mountains Pleasant Grove Uplands	North Carolina	Burke	2016	<100	low

Gunpowder Creek	North Carolina	Caldwell	2012	<100	low
Killian Crossroads	North Carolina	Catawba	2010	<100	low
Pott Creek	North Carolina	Catawba	2012	<100	low
Beaverdam Crk at First Broad River	North Carolina	Cleveland	2011	<100	low
Buffalo Creek: Potts Creek	North Carolina	Cleveland	2012	<100	low
Buffalo Creek: Ravine	North Carolina	Cleveland	2007	<100	low
Hickory Creek - UT (Shelby High School)	North Carolina	Cleveland	2016	<100	low
Boulder Creek Subdivision - Jordan Road	South Carolina	Greenville	2016	<100	low
Gateway Elementary School	South Carolina	Greenville	2017	<100	low
Fanjoy Road Site	North Carolina	Iredell	2015	<100	low
Levan Family Farm	North Carolina	Iredell	2013	<100	low
Lincoln County, SR-1314	North Carolina	Lincoln	2014	<100	low
Northeast Lincolnton: UT Walker Branch	North Carolina	Lincoln	2009	<100	low

Table 2--Population resilience categories by county for dwarf-flowered heartleaf.

County	Very High	High	Moderate	Low	Totals
Alexander	1		1	1	3
Burk/Cata/Cald			1		1
Burke	2		3	1	6
Caldwell	2	2		1	5
Catawba	4	2	3	2	11
Cherokee	1				1
Clev/Ruth	1				1
Cleveland	4	1	5	4	14
Gaston			1		1
Greenville				2	2
Iredell			1	2	3
Lincoln	1		1	2	4
Polk	2		2		4
Rutherford	7		2		9
Spartanburg	2				2
Totals	**27**	**5**	**20**	**15**	**67**
% of total	*40*	*7*	*30*	*22*	*100*
Cumulative %	*40*	*48*	*78*	*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 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 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: NCNHP).

Commented [RNR2]: I received a VM from Tim Bassette of NCDOT on 2/27. We can use the DOT trend numbers…I think that adds two or three "Sites" to the table.

Trend	**Survey**	**Site**	**2016 estimated number of plants (Rosettes)**	**2016 are 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	Rhyne 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
	NCNHP	Broad River: Henson's Creek, Brice, & Sandy Mush Outcrop (EO 099)	106,940	83.39
	NCNHP	Broad River: Cleghorn Creek, US 221 (EO 176)	6,750	7.24
	NCNHP	Cowpens National Battlefield (SC EO 016, 017, 018)	2,823	6.05
	NCNHP	Peters Creek Preserve (SC EO 011)	3,306	8.98
	NCNHP	Blalock Reservoir (SC EO 007, 031)	3,505	7.59
Decreasing	NCNHP	Second Broad River (Forest City Industrial Complex) (EO 154)	2,576	4.74
	NCNHP	South Fork Catawba River: Jacob Fork, Camp Creek (EO 158)	123	0.09

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

A previous habitat suitability study attempted to quantify the habitat requirements for dwarf-flowered heartleaf. A model was created to predict habitat suitability, and based on the model results, the strongest habitat correlations were slope, aspect, soil type, elevation, and land use (Wagner 2015). With this model in mind, 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 2.

Source Data and Model Variables

Fifty three, 10-digit hydrologic units (HUC) comprise the analysis extent. In North Carolina, it includes all 10-digit HUC that fall within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*. In South Carolina, we also included all 10-digit HUC that fell within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*, 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. These data were in polygon format and digitized at a scale that accurately identified the boundaries of the individual population areas. 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 in the last 10 years (2007). 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.

Commented [RNR3]: All SC data is in point form. The polygon data for SC came from NCNHP.

Model Development

We used Maxent software (version 3.4.1) for species habitat modeling (Philips 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, SSURGO drainage class, SSURGO hydrologic group, aspect 9-class, aspect 5-class, slope, and maximum annual temperature.

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 2 shows the model output. The minimum cutoff value (to determine if an area is considered potential habitat for a species) of 0.406 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 predictions to focus on the typical habitat conditions for this species. The total area ranked greater than 0.406 in the Maxent model was just 6.39% of the total analysis area (Table 4).

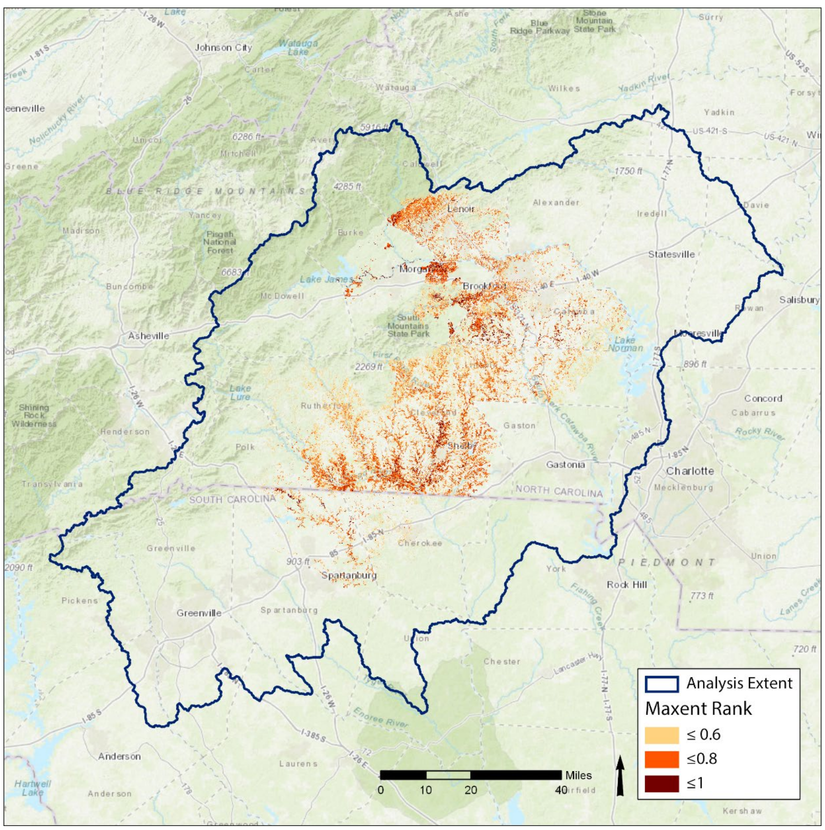

Figure 2-Maxent model output map

Table 4-Area estimates of the Maxent model

Maxent Score	Acres	Square Miles	Percent of Total
0.406 and greater	321,262.37	501.97	6.39%
0.6 and greater	146,712.65	229.24	2.92%
0.8 and greater	22,677.96	35.43	0.45%

The average area-under-curve (AUC) score for the replicate Maxent model is 0.849. The AUC is calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1 and may be interpreted as a single test statistic that assesses model performance, indicating the ability of the model to correctly classify the occurrence data used. The model performed well in its predictions, with a mean AUC of 0.849 (AUC value of 0.5 is no better than random; AUC<0.5 is worse than random; AUC>0.5 is greater predictive power than random; Baldwin 2009).

The Maxent output supplies estimates of the relative contributions of the environmental variables to the Maxent model (Table 5). SSURGO mukey is the top contributing variable. One hundred and thirty-five individual soil types are present within the polygon boundaries of the *Hexastylis naniflora* element occurrences. Many of these individual soil types are part of soil complexes and are separated by things such as percent slope, erosion, how stony/rocky, and amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25 to 60 percent slopes, very stony (12.9% of total). However, collectively the Meadowfield soils only comprised 13.5% of all soils). The individual Pacolet soil types were very common and collectively comprise 36% of all soil types present. Woolwine soils were also collectively common, comprising 10% of all soils present.

The minimum annual average temperature range in the analysis extent is 39 – 51 degrees Fahrenheit. The majority of the *Hexastylis naniflora* element occurrences (92%) 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 (81%) are found in the 47 – 49 inches per year range.

Piedmont forested landcover habitats dominate the land area of the element occurrences. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier (52%), Southern Piedmont Mesic Forest (10%), Southern Piedmont Small Floodplain and Riparian Forest (3.6%), and Southern Piedmont Dry Oak-Pine Forest – Loblolly Pine Modifier (2.3%) collectively comprise 72% of the element occurrences area. Unfortunately, non-native habitats are also present. Evergreen Plantation or Managed Pine (8%), Harvested Forest – Grass/Forb Regeneration (7%), Developed, Open Space (5%), Pasture/Hay (2.5%) 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 landcover classes, but each at small percentages.

The landcover majority classification scheme reduces the total number of landcover classes present in the analysis extent from 23 to 12. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landcover class (56%). 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 landcover area representation in the landcover majority layer suggests that many *Hexastylis naniflora* population areas are situated in areas impacted by disturbed landcover. This is likely due to urban encroachment and increasing fragmentation of habitats.

The landcover Hexastylis grouping reveals the amount of disturbance present in Hexastylis population areas. Landcover classes grouped as disturbed comprises 26% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, hardwood forest 11%, and riparian 3.6%. Open water, evergreen and barren landcover groupings are all at less than 1% each.

Geomorphons revealed that the majority of *Hexastylis naniflora* element occurrence areas are situated in concave landforms. Geomorphon categories hollow (15%), valley (35%), and depression (17%) collectively comprise 67% of all *Hexastylis naniflora* population areas. Flat landforms comprise 22.5% of the area and convex landforms the remaining 10.5%.

Within the analysis extent, the range of elevation present is 335 – 5,265 feet. For *Hexastylis naniflora*, the prime elevation range is from 666 – 896 feet (54% of total element occurrence area). A lesser elevation range is present from 935 – 1,165 (35% of total element occurrence area).

Table 5-Percent contribution of the environmental variables

Environmental Variable	Percent Contribution
SSURGO mukey	23.3%
Minimum Annual Temperature	20.7%
Average Annual Precipitation	14.6%
Landcover	13%
Landcover Majority	9.5%
Landcover Hexastylis Grouping	7.3%
Geomorphons	6.4%
Elevation	5.2%

We performed an Analysis of Variance test to investigate the relationship between Maxent scores and current resilience of populations (Table 6). There are significant differences in the average Maxent scores between the four resilience categories (p = 0.01) and the mean Maxent score increases as population resilience increases for low to very high. It appears the model gives us some predictive ability regarding habitat quality, where higher Maxent scores, on average, result in higher population resilience.

Commented [RNR4]: Suitability?

Table 6-Results of the ANOVA investigating relationships between Maxent scores and current resilience groups for dwarf-flowered heartleaf.

Commented [RNR5]: Mark sent a new table.

Groups	*Count*	*Sum*	*Average*	*Variance*
low	13	5.240363	0.403105	0.124194
moderate	20	8.851696	0.442585	0.040139
high	4	2.292114	0.573028	0.039821
very high	27	16.66603	0.61726	0.020717

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.563333	3	0.187778	3.870253	0.01346	2.758078
Within Groups	2.911089	60	0.048518			
Total	3.474421	63				

Current Species Representation

Representation describes the ability of a species to adapt to changing environmental conditions. We lack genetic and ecological diversity data to characterize representation for dwarf-flowered heartleaf. In the absence of species-specific genetic and ecological diversity information, we typically evaluate representation based on the extent and variability of habitat characteristics across the geographical range. However, the dwarf-flowered heartleaf has a very limited range, and after consulting with experts, we decided delineating representative units was not appropriate for this species.

Current Species Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events (such as a rare destructive natural event or episode involving many

populations). Redundancy for dwarf-flowered heartleaf is the total number and resilience of population segments and their distribution across the species range. As stated previously, there are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years, and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low); 2 (unknown). The populations are spread across the range, although a majority occur in North Carolina. Although, there appears to be adequate redundancy within the range of dwarf-flowered heartleaf, the species range is very small, making it potentially vulnerable to catastrophic events. Thus, we classify redundancy as inherently low for the species.

Commented [RNR6]: 67 or 68?

Commented [RNR7]: The unknowns were classified as low for purposes of the model.

Commented [RNR8]: For my edification - Is this a matter of scale? What catastrophic event would wipe out 12 counties? Anything other than climate change (large scale)? Is that enough to make an over-arching statement that redundancy is low.

INFLUENCES ON VIABILITY

Hexastylis naniflora populations occur in rapidly growing urban areas with expanding suburbs of Charlotte, NC, to the east; Hickory, NC, to the north; and Greenville and Spartanburg, SC, to the south. At the time of listing, it was determined that the species was most threatened by habitat loss due to the conversion of land to residential, commercial, and industrial use in these areas. In addition to threats associated with residential, commercial, and industrial development, other documented threats include habitat loss from land conversion to agricultural use, timber harvest, hydrological alterations from the damming of ponds, impacts from grazing cattle, ORV damage, trampling from foot traffic, invasive species, highway or road improvements, and erosion or siltation (NCNHP 2016, Robinson and Padgett 2016). Climate change may exacerbate these risk factors through changes in temperature and precipitation.

Threats were assessed for populations monitored by NCNHP during 2012-2016 (Robinson and Padgett 2016), and EOs were reviewed for other documented threats to populations. Indirect or direct threats that were observed, inferred, or suspected to have an impact on populations were recorded and assigned a ranking based on their severity, scope, and immediacy from field observations. The rank for each threat factor determines the overall value for each threat observed at each population. No significant changes in threats within populations were noted from 2012-2016. Threats observed during these years included development, incompatible forestry practices, agriculture, trampling, invasive exotic species, sedimentation, erosion, and road construction.

Below, we summarize primary threats to the viability of dwarf-flowered heartleaf. Primary influences will be carried forward in our future projections in the next section.

Human Population Change

Increasing human populations drive development. With increases in population, there will be increasing conversion of open space to more impervious cover, with a subsequent increase in roads and other associated infrastructure. Increases in roads and impervious cover have the potential to lead to habitat loss and/or fragmentation, a primary risk factor for dwarf-flowered heartleaf. Tables 1-2 and Figures 1-2 show the estimated human population increases for North

Carolina and South Carolina counties within the range of the species. The most populous counties include Greenville and Spartanburg in South Carolina, and Catawba, Gaston and Iredell counties in North Carolina.

Table 1-Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

County	2018	2023	2028	2033	2037
Alexander	38609	39,244	39,686	39992	40169
Burke	90865	93,124	95,382	97644	99452
Caldwell	83919	86,723	88,689	91126	92870
Catawba	157424	159,799	162,175	164549	166447
Cleveland	98862	99,685	100,004	100128	100170
Gaston	221112	227,667	237,344	245276	252388
Iredell	179740	195,623	211,501	227383	240088
Lincoln	84494	91,034	96,865	103069	107858
Polk	21273	21,823	22,288	22681	22955
Rutherford	67880	68,154	68,283	68341	68368

Commented [RNR1]: I'm wondering if there is a better way to display this information. Example -for Alexander County, the difference between 2037 and 2018 is approx.. 82 people per year (about 1,500 people total). Compare that to Iredell with the addition of approx.. 3,100 people per year (about 60K total people). Maybe an average % increase or average rate of change would be a simpler way to get the point across. I think the graph gets at this but at the current scale doesn't seem to show it well.

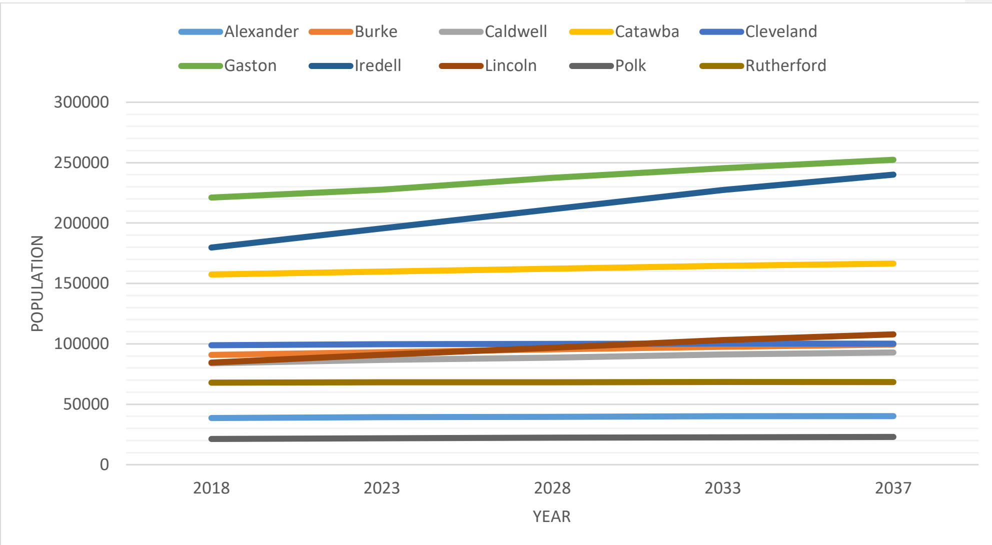

Figure 1- Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

Table 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
Greenville	492,890	517,740	542,290	567,010
Spartanburg	310,220	323,550	336,810	350,110

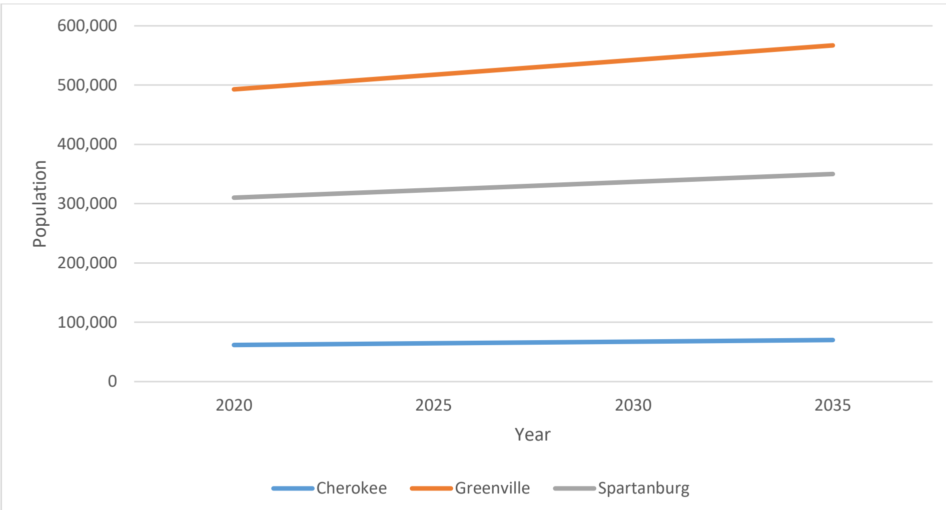

Figure 2- Human population projections for South Carolina counties within the range of dwarf-flowered heartleaf. *Source: U.S. Census Bureau, 2000 Census and 2007 Population Estimates. Population projections calculated by South Carolina Budget and Control Board, Office of Research and Statistics.*

Development

A large number of the known populations occur near expanding urban areas and are threatened by the residential, commercial, and industrial development associated with this growth. Populations occurring in more rural areas are threatened by habitat alteration or loss from land conversion to pasture or other agricultural uses, cattle grazing, intensive timber harvesting, residential construction, and construction of small ponds.

A 2011 review of existing NHP EOR data revealed that all or portions of 26 populations (24% of the total) had been directly or indirectly impacted through development projects or other causes such as trash disposal, expansion of residential lawns, cattle, or invasive exotics (NC NHP 2010; SCDNR 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

foreseeable within 42 of the 108 populations (corresponding to 39% of all known populations). Of these 42 populations, all or portions of 22 (50%) had been adversely impacted by activities requiring ESA Section 7 consultation with the USFWS. The fact that nearly 20% of all known populations had been subject to formal Section 7 consultation illustrates the threats faced by the species.

Commented [RNR2]: We mentioned 113 populations in the 2016 reports. I believe 108 comes from the 5-YR review. Can that be clarified?

The most recurrent source of habitat destruction, and certainly the most common trigger for Section 7 consultations involving *H. naniflora* is road and bridge improvement projects. Ten of the 27 largest populations (containing more than 1,000 rosettes) have been the subject of Section 7 consultations between the USFWS and the NCDOT. Collectively, these projects have adversely impacted or are currently expected to impact some 22,135 rosettes. In most cases the Section 7 process has resulted in avoidance or minimization of adverse effects through relocation of plants and/or commitments of on-site protection to those plants remaining (post-construction) within NCDOT right-of-way (ROW).

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 consultations with the USFWS. Examples of these activities include the maintenance or expansion of hydroelectric and drinking water reservoirs, construction of an industrial development complex, and maintenance activities (in compliance with Federal Aviation Administration standards) at a regional airport. Collectively, these activities have involved the loss or relocation of several thousand rosette.

Blalock Reservoir in Spartanburg County, South Carolina was once estimated to contain the largest population of *H. naniflora*, with over 11,000 rosettes reported here in 1997 (JJ&G, 1998). This population was the subject of a section 7 consultation as a result of a proposal to raise the elevation of Blalock Reservoir, which provides water supply storage to Spartanburg County and the City of Spartanburg (USFWS, 2001). Approximately one-third of this population was directly threatened by inundation, and the Federal agency committed to the relocation of some 3,054 rosettes to remaining areas of occupied habitat around the reservoir. At the conclusion of formal section 7 consultation, the USFWS anticipated that as many as 6,619 rosettes (assuming

Commented [RNR3]: Still wondering why this report calls out Blalock Res.

that all transplants survived) would be afforded protection through restrictive covenants placed on properties owned by the Spartanburg Water System (SWS) surrounding Blalock Reservoir. However, this population was last reported to contain a mere 1,400 rosettes (Newberry, 2006), and has twice since been impacted by encroachments from adjacent landowners (Newberry, 2009; Schneider, 2006, and JJ&G, 2006). Some of these apparent declines could be partially an artifact of incomplete survey effort, in that the exhaustive surveys which led to the 1997 estimate (of 11,000 rosettes) have never been repeated. However, it seems unlikely that plants occurring on privately owned shoreline not subject to restrictive covenants would be any more stable than those occurring on properties specifically protected and managed for the species (by SWS).

Invasive Species

Several of the known populations of dwarf-flowered heartleaf occur on steep ravine slopes which also support stands of mixed hardwoods with an understory of mountain laurel (*Kalmia latifolia*) or *Rhododendron spp*. These stands are often very dense and reduce the amount of light reaching the dwarf-flowered heartleaf plants growing below. Under these conditions the plants often show reduced vigor and reduced flower and fruit production. Careful, selective logging or natural tree fall and limited understory removal would open up these populations to more light. Additional light, if not accompanied by increased siltation from the intensive soil disturbances associated with forest clear-cutting, probably would benefit these populations (Gaddy 1981).

Commented [RNR4]: Think I mentioned this before but these are not NNIS. I don't want an outside reader thinking that they are.

Invasive exotic plant species are rampantly spreading throughout riparian corridors and ravines across the range of this species. Invasive exotics such as English Ivy (*Hedera helix*), Chinese privet (*Ligustrum* spp.), Japanese honeysuckle (*Lonicera japonica*) and Japanese Nepal grass (*Microstegium vimineum*) are known to threaten several populations; however, the scope and magnitude of this threat has not been comprehensively assessed. This threat requires active management in order to be successfully abated. At present, the majority of protected populations are secured against habitat conversion, but lack designated managers with the technical expertise and available resources (funding and personnel) to address this threat.

Climate Change

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

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

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

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 (NCILT 2012, p.27; IPCC 2013, p.7):

- More frequent drought
- More extreme heat (resulting in increases in air and water temperatures, Figure 5-3)

- Increased heavy precipitation events (e.g., flooding)
- More intense storms (e.g., frequency of major hurricanes increases)
- Rising sea level and accompanying storm surge

In recent years, the Southeast has experienced moderate to severe droughts that many observers have implicated in population declines and poor transplant survivorship (NC NHP, 2010). A wildfire, presumably brought on or at least exacerbated by drought conditions, burned portions of one of the largest known populations in 2009 (Foothills Landfill in Caldwell County; Golder and Associates, 2009). Accelerated climate change is expected to increase the frequency and extent of drought conditions across the southeast (Karl, et al. 2009). The extent to which these climate changes will significantly affect populations of dwarf-flowered heartleaf is currently unknown.

Commented [RNR5]: Fire may not be bad, we don't know. Maybe we need to clarified what type of wildlife would be considered catastrophic. I read this as fire being a negative. From the Range-wide report - Additionally, a dormant season wildfire in Caldwell County did not show evidence of negative impacts to a population in Caldwell County (USFWS 2010).

Appendices 3a and 3b gives summary reports on historical and future predicted climate parameters from the USGS National Climate Change Viewer for both North Carolina and South Carolina. As discussed above, the trend for these States is as it is for the Southeast in general: more frequent drought, more extreme heat, and increased precipitation events. If these predictions hold true, dwarf-flowered heartleaf habitat would likely be impacted through increased evaporative rates and decreased soil moisture (Appendices 3a and 3b), increased potential for catastrophic wildfire events, as well as potential disruption of stream bank morphology through increased flooding events.

From:	Marshall, Michael E
To:	Mason, Suzanne; Amoroso, Jame; Matt Estep; tpbassette@ncdot.gov; Endries, Mark; Reid, Rebekah N; Becker, Drew N; Stephanie DeMay
Subject:	Re: HENA Drafts
Date:	Thursday, March 15, 2018 10:26:07 AM
Importance:	High

Hello all,

Just an update and a slight change of course for everyone. We had originally planned on sending out the Future Conditions section for review on March 12th....however, in the interest of not sending you a ton of different materials to review a bunch of times, we've decided to include the Future Conditions in a full draft of the SSA for your next review. That draft will have all of your comments and edits from previous sections integrated into the document, so you'll want to focus your review on the final section (Future Conditions). I anticipate sending that out to the technical team by April 9 (probably a bit earlier), at which point we will ask for your review turn-around to be about 1 week...after we integrate your final edits, we will send out for peer review.

If you have any questions, please let me know.

Thanks!

Mike

On Thu, Feb 22, 2018 at 9:19 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:

> Good morning Team!
>
> Sorry for the delay, but here are the next two sections of the HENA SSA attached for your consideration and review, with appendices attached as well. These sections are Current Conditions and Influences on Viability. As you review and provide comments on these sections, we will be working on the Future Conditions section, which will be the final section of the SSA.
>
> Please provide your edits and comments to these documents in track changes by **COB Friday March 2nd.**
>
> Thanks you so much for your help and input on all of this. And, if at any time you have any questions, please feel free to contact me or Rebekah.
>
> Take care and have a great weekend!
>
> Mike
>
> --
>
> 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.

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Subject:	Re: HENA Drafts
Date:	Monday, April 23, 2018 2:59:58 PM
Attachments:	Draft HENA SSA_04232018.docx
Importance:	High

Good afternoon all!

It's that time....I've attached a draft of the entire SSA for your review. I'll need to send 2 separate emails; the second email will have the appendices. The attached draft includes all sections you have already reviewed with your comments and suggested edits integrated....and, future conditions, which you will be seeing for the first time. One of the biggest changes we made from the last sections you reviewed was to go back a little further in considering what a current population is....and, focusing on the likelihood that those EOs that we did not include, may very will still persist....you'll see statements to that effect, and how we dealt with this in the "rediscovery" of some populations in 2 of our future scenarios.

As far as when we need your comments....we will need your review sent back no later than COB Monday May 7th. This will ensure that we have adequate time to send out for external peer review before we finalize the report.

Thank you so much for your involvement, and everything you've done for the conservation of the species. We look forward to your feedback!

Take care,

Mike

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DRAFT Species Status Assessment Report

for

Dwarf-flowered Heartleaf (*Hexastylis naniflora*)

Version 1.0

xx-xx-201x (date)

U.S. Fish and Wildlife Service

Region 4

Atlanta, GA

ACKNOWLEDGEMENTS

This document was prepared by Michael Marshall (U.S. Fish and Wildlife Service [Service]-Texas A &M Natural Resource Institute [NRI]), Rebekah Reid (Service), Mark Endries (Service), and Stephanie DeMay (Texas A&M NRI). External species expertise, guidance, and document reviews were provided by technical team members Suzanne Mason (North Carolina Natural Heritage Program [NCNHNP]), Jame Amoroso (NCNHP), Matt Estep (Appallachain Statue University), and Laura Robinson (NCNHP). Peer review was provided by ________.

Table of Contents

Chapter 1: INTRODUCTION

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 would 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;

for example, birth versus death rates and population size. Highly resilient populations are better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities.

- **Redundancy** describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events (such as a rare destructive natural event or episode involving many populations).
- **Representation** describes the ability of a species to adapt to changing environmental conditions. Representation can be measured by the breadth of genetic or environmental diversity within and among populations and gauges the probability that a species is capable of adapting to environmental changes. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the geographical range.

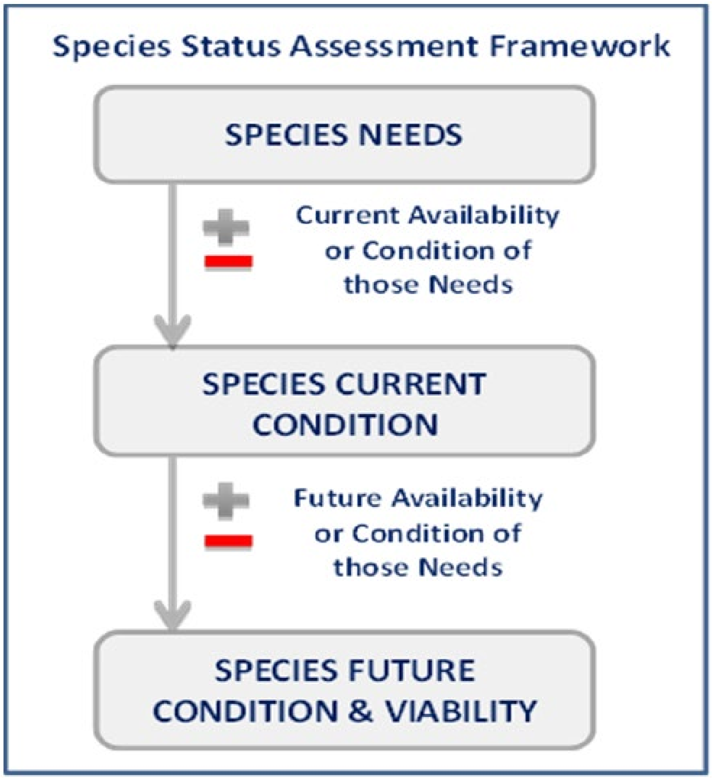


Figure 1.1. Species Status Assessment Framework

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.

Chapter 2: SPECIES BIOLOGY

In this chapter, we provide basic biological information about the dwarf-flowered heartleaf, including its taxonomic history, species description, distribution, life history traits, and habitat characteristics. We then use this information to outline the resource needs within various life stages of dwarf-flowered heartleaf. Here we report those aspects of the life history of the dwarf-flowered heartleaf that are important to our analysis.

Taxonomy and species description

Dwarf-flowered heartleaf is a rare, low growing herbaceous plant in the birthwort family (Aristolochiaceae). The species was described by Blomquist (1957) in his revision of the North American members of the genus *Hexastylis*. The dwarf-flowered heartleaf has been recognized as part of the Virginica Group, and this group was further subdivided into three Subgroups: Virginica, Shuttleworthii, and Heterophylla (Blomquist 1957; Whittemore and Gaddy 1997). Three species have been recognized in the Heterophylla complex, *Hexastylis naniflora, H. heterophylla* and *H. minor*, and field biologist have generally recognized that considerable morphological overlap occurs (Murrell et al. 2007). One of the main concerns regarding this complex was the inability to distinguish between species without access to fresh flowers. Even with fresh flowers, Blomquist (1957) and Gaddy (1987) still recognized considerable overlap in flower morphology making species delineation difficult.

Murell et al. 2007, conducted a comparative genetic analysis using Inter Simple Sequence Repeats, and were unable to find banding patterns that could be used to separate *H. naniflora* from the other members within the complex. However, based on biogeographical, ecological, molecular, morphological, as well as micromorphological work, their results show that *H. naniflora* is a well-defined species.

Although there has been considerable disagreement on the generic distinctiveness of *Hexastylis* and *Asarum* (Barringer 1993 and Kelly 1997, 1998, 2001), a recent phylogeny estimate using chloroplast genes supports that *Hexastylis* is a monophyletic clade and therefore should be recognized as a genus (Niedenberger 2010). Additionally, most North American publications recognize *Hexastylis* at the generic level (Flora of North America 1997, Weakley 2015).

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

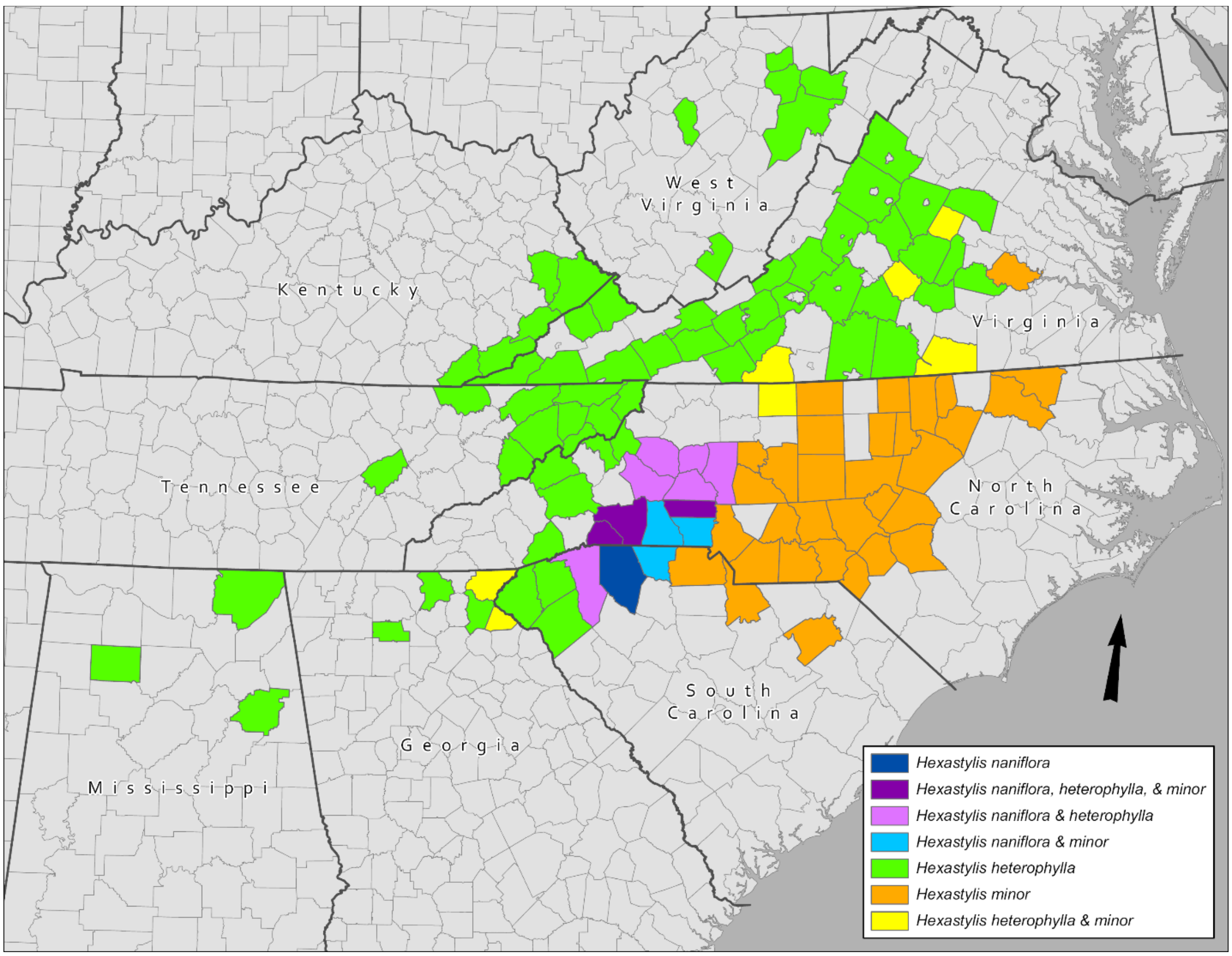


Figure 2.1. Distribution map showing county records for the three species in the *H. heterophylla* complex. Data was gathered from herbarium specimens, Element Occurrence Records (EORs) sheets and field studies. Dots within *H. heterophylla* counties indicates co-occurrence with *H. minor*. Light dot within *H. naniflora* counties indicates co-occurrence with *H. heterophylla*, dark dot indicates co-occurrence with *H. minor*. *Based on Murrell et al. 2007.*

The most outstanding characteristic of this species is the small flowers, which are one of the smallest of any species in North America (Blomquist 1957). The plant's heart shaped leaves are dark green in color, evergreen, and leathery, and are supported by long thin petioles from a subsurface rhizome. The shape of the leaf blades, their pattern of variegation, and the ridged reticulation inside the calyx-tube, place this species inside the Virginica group. It differs from all the other members of this group, aside from the small flowers, in having no flare in the calyx-tube. Maximum height rarely exceeds 15 centimeters (cm). The jug shaped flowers are usually beige to dark brown in color and appear from mid-March to early June. The flowers are small and inconspicuous and are found near the base of the petioles. The fruit matures from mid-May to early July (Blomquist 1957, Gaddy 1980, 1981). Characteristics that distinguish it from other *Hexastylis* species are found in floral structures and pollen characters (Gaddy 1987, Padgett 2004, Niedenberger 2010). *H. naniflora* has a smaller calyx tube orifice, which is typically 5mm or less (sometimes up to 7mm) and the ovary is half-inferior, rather than superior (Blomquist 1957, Gaddy 1987, Padgett 2004, HDR 2005). Pollen surface features have also been shown to be an effective character to identify *H. naniflora*, as it has a microporate surface and, unlike any other *Hexastylis* species, lacks gemmae entirely (Padgett 2004, Niedenberger 2010).

Distribution

Although dwarf-flowered heartleaf is restricted in range, it is not as rare as once thought (USFWS 2010, NCNHP 2016). When dwarf-flowered heartleaf was federally listed in 1989, the listing rule described 24 extant "populations" (and one extirpated population) distributed across eight counties in the upper Piedmont of North and South Carolina. Since 1989, the range has expanded to include four additional counties in North Carolina. In North Carolina, it is found in Alexander, Burke, Caldwell, Catawba, Cleveland, Gaston, Iredell, Lincoln, Polk, and Rutherford Counties. In South Carolina, it is in Cherokee, Greenville, and Spartanburg Counties. As of 2016, the distribution of this species consisted of 113 populations distributed across 12 counties in these two states (Figure 2.2). Soils seem to be an important factor determining distribution of the species, restricting dwarf-flowered heartleaf to an area from near Charlotte, North Carolina west to the foot of the mountains near Rutherfordton, North Carolina, and from Hickory, North Carolina southward to just south of Spartanburg, South Carolina (Figure 2.2).

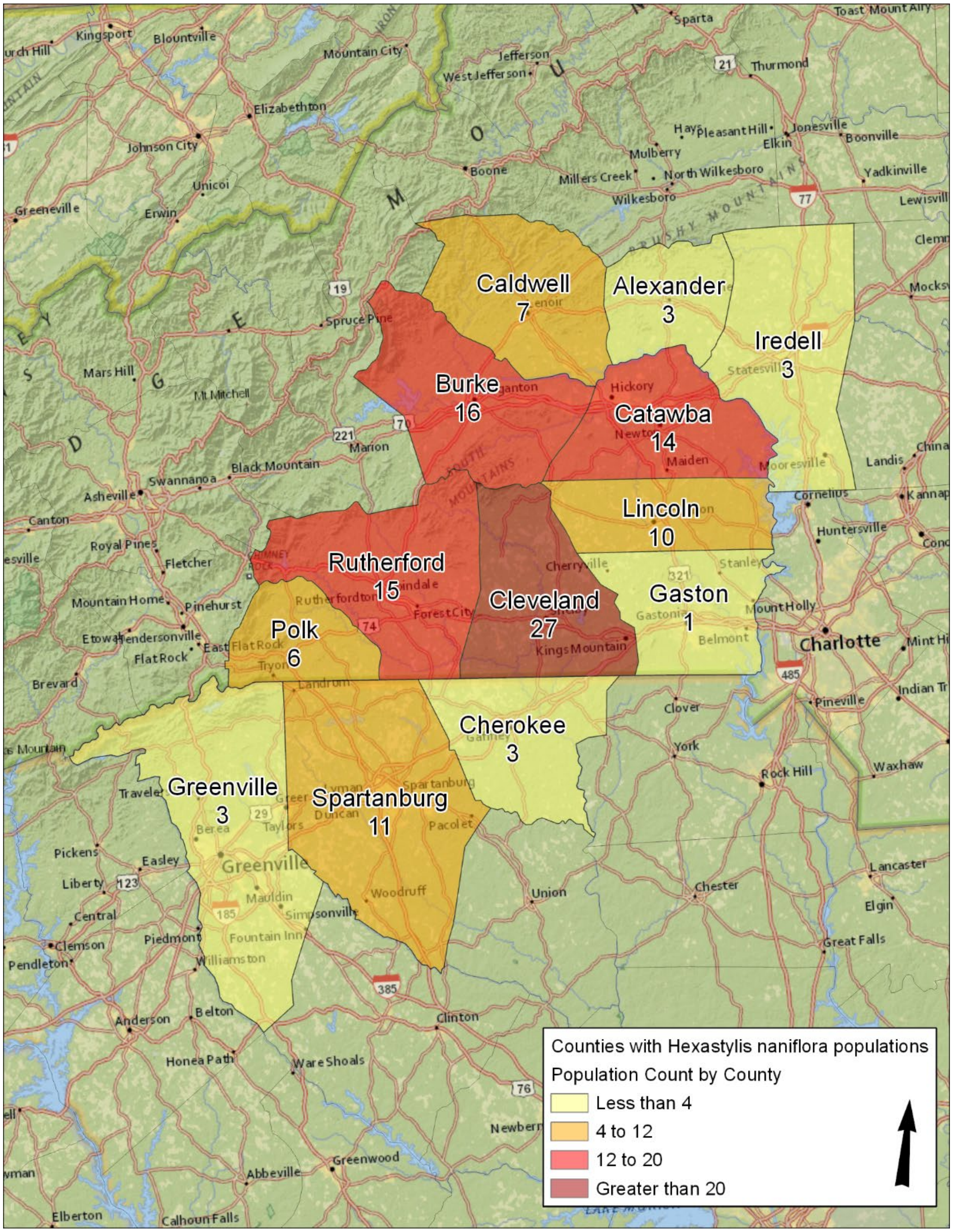


Figure 2.2. Current county distribution for dwarf flowered heartleaf, with associated number of known populations within each county.

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 have aggregated smaller sites into populations according to subjective criteria which have never been explicitly defined. This generates discrepancies among sources with respect to the abundance and distribution of the species, with the net result being that available data are usually not comparable from one source to the next. We describe how the numerous small, site-specific locations containing *H. naniflora* have been aggregated into proxies for 113 biological populations for purposes of this review, using mapping standards devised by NatureServe and its network of Natural Heritage Programs, in the Species Needs section of this report.

Life History

Demographics

The Service is aware of a single effort to collect demographic-level data (survivorship and recruitment of tagged individuals) for dwarf-flowered heartleaf. This effort was conducted during the 1990-1991 field seasons, within a portion of the Peters Creek population in Spartanburg County, SC (Newberry, 1993). This study demonstrated a 96.1% survival rate over these two consecutive seasons, with 50% of the mortality occurring in plants located at the highest position on the forested slope (away from the adjacent floodplain). Mortality was highest in small plants bearing fewer than four leaves. Plant size was variable, with the largest plant bearing 45 leaves and 33 flowers, and situated in the floodplain. In general, plants located in the floodplain were larger than plants located on adjacent slopes. The percentage of flowering plants averaged 70%, with the highest frequency of flowering occurring among plants situated in the floodplain (USFWS 2010).

Pollination and Dispersal

The pollination of Hexastylis has not been well studied but the genus was thought to be pollinated by insects including flies, wasps, and thrips (Otte 1977). Additionally, Lengyel et al. (2010) described how, within the family Aristolochiaeae, more than 50% of the plant lineage is myrmecochorous (seed dispersal by ants). This supports Gaddy's work (1986), which found three species within the Hexastylis Heterophylla subgroup (*H. heterophylla, H. naniflora, and H. minor*), which employ myrmecochory as a method for seed dispersal.

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

Habitat

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

Dwarf-flowered heartleaf occurs on piedmont uplands on acidic sandy-loam soils that are very deep and moderately permeable (Gaddy 1981, 1987). Typical habitats for this species include mesic to dry bluffs, slopes, or ravines in deciduous forests that are frequently associated with *Kalmia latifolia* (Padgett 2004, Weakley 2015, USFWS 2015), or in moist soils adjacent to creeks, streamheads, or along lakes and rivers. Plants have been observed to grow larger and 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 dwarf-flowered heartleaf, which may be used for helping identify the species when not in flower (relative to other *Hexastylis* species habitat preferences), find new populations, or identify suitable sites for transplants. A model was created to predict habitat suitability to determine how many EOs are found within habitat considered fair to excellent (Figure 2.3; Wagner 2015). Based on the model, the strongest habitat correlations were that the slope aspect was north-facing, soil type is Pacolet sandy loam, elevation was between 230-260m, percent slope is 8-10%, and land use is deciduous forest (Wagner 2015). Populations found in areas with a percent slope of greater than 28, soil codes other than 6, 7, or 11, or elevation less than 199 m or greater than 415 m are unlikely to be *H. naniflora.* The model accurately predicts habitat suitability at a local scale 81% of the time.

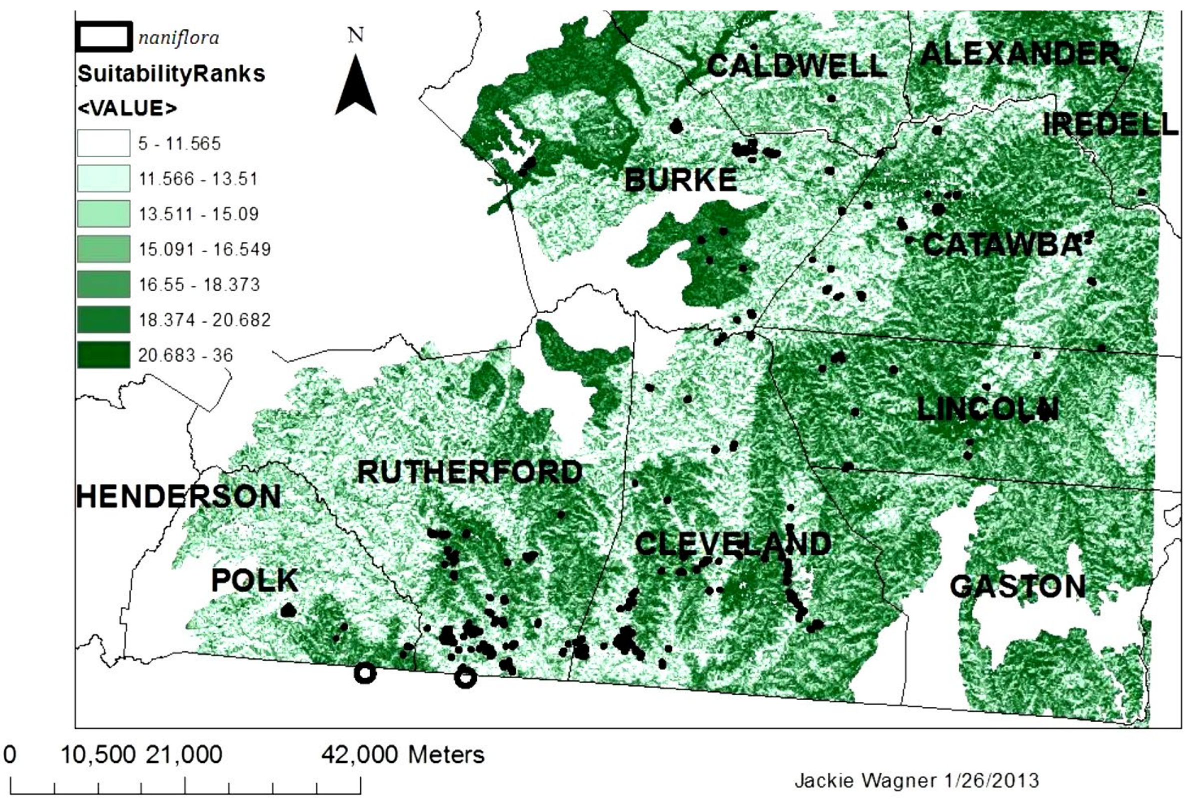


Figure 2.3. The site suitability ranks based on five habitat variables across the counties where *H. naniflora* is known to exist in NC. The smaller numbers indicate a higher rank and lighter green areas denote more suitable habitat. Known populations of *H. naniflora* are outlined in black.

Soils

The species appears to be restricted to Pacolet sandy loam, Madison gravelly sandy loam, and Musella fine sandy loam soils (Gaddy 1981,1987). The species grows in acidic soils along bluffs and adjacent slopes, in boggy areas next to streams and creekheads, and along the slopes of nearby hillsides and ravines (Gaddy 1980, 1981). The plant is primarily found inhabiting north- to northwest-facing slopes, bluffs, and ravines in close proximity to creeks or streams. Within these areas exists the soil type required for *H. naniflora* to grow. It grows primarily on well-drained, sandy, acidic soils, and will not grow in heavy clay (Gaddy 1981).

The results of soil samples analyzed at the Clemson Soil Lab suggest that major differences in soil chemistry exist between the species in the *H. heterophylla* complex. Statistical analysis of the soil samples showed that many of the basic elements were significantly different among the three species. Those significant differences occurred in Phosphorous (P), Potassium (K), Magnesium (Mg), Zinc (Zn), Manganese (Mn), (Na), Sodium, and Cation Exchange Capacity (CEC). Slightly significant differences were seen in Buffer pH (Bu pH), and Acidity.

Soil chemistry showed marked differences between the species in the complex. The results indicated that soil chemistry is very different between *H. naniflora* and *H. minor* localities. The results also show that *H. heterophylla* and *H. naniflora* are found in soils where the chemistry is more similar, but still showed significant differences. It would appear that differentiation in soil types could be used as a proxy for species delineation. The soil analysis also indicates that soils must be considered when trying to select sites for relocation of imperiled populations of *H. naniflora*.

Thirteen population sites in North Carolina and South Carolina were examined using the Carolina Vegetation Survey (CVS) method to compare species richness between the three species of the *Hexastylis heterophylla* complex. The analysis did not show statistically significant differences among the three species in the *H. heterophylla* complex. However, *H. naniflora* appears to have an association with three oak species that is lacking in the 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 the other two species in the complex. This may be the result of some microbial need or specific soil nutrient required for those species to occur in the same habitat.

Fire

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

Genetics

Analyses on ecology, morphology, soil chemistry, pollen, and molecular genetics have been evaluated for *Hexastylis naniflora* to determine the boundaries within the *Hexastylis heterophylla* complex, which consists of *H. heterophylla*, *H. minor*, and *H. naniflora* (Murrell 2015, Wagner 2013, Niedenburger 2010, USFWS 2010, Murrell et al. 2007, Padgett 2004). These analyses support the continued recognition of these taxa as well-defined, discrete species. Scanning electron microscopy (SEM) consistently distinguished *H. naniflora* from other members of the *H. heterophylla* complex based on pollen microscopy. Principal Components Analysis of floral characters and soil chemistry also consistently distinguished *H. naniflora* from *H. minor* and *H. heterophylla*. However, efforts to obtain consistently distinct banding patterns using Inter Simple Sequence Repeats (ISSRs) were unsuccessful at distinguishing *H. naniflora* from other members of this group (Murrell et al., 2007). These results were based upon an extremely small sample size (n=10 *H. naniflora* individuals), and therefore warrant further investigation.

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

The preliminary findings of this study suggest that populations in the southern range of dwarf-flowered heartleaf exhibit a more uniform genetic pattern, with some possible hybridization with *H. minor*. Populations in the northern part of the range appear to have hybridized with both *H. heterophylla* and *H. minor*, although there are still individuals with "pure" *H. naniflora* genotypes in the northern range (Murrell 2015). It is critical to note that although these data provide anecdotal evidence of hybridization with the *Hexastylis heterophylla* group, intraspecific variation may be caused by forces other than hybridization, such as convergent morphological evolution (Dobzhansky 1937), or the species is in the process of speciation and this study shows a case of incomplete speciation (Murrell 2015), and/or other environmental factors are at play (Wagner 2013). On May 11, 2016 a meeting was held with USFWS, NCNHP, NCDOT, and ASU to discuss the status of *H. naniflora* and the current work being conducted among the agencies (Amoroso 2016). Based on discussions during this meeting, the results of this study reported by ASU to NCDOT in 2015 are preliminary. Dr. Matt Estep (ASU) provided additional preliminary results to NCNHP in May 2016, showing which populations were sampled, sample size, and percent of samples that show evidence of hybridization, and hybridizing with which species. ASU continues to work towards a more definitive explanation of the variation in the *H. heterophylla* complex (Murrell 2015, Amoroso 2016).

CHAPTER 3: SPECIES NEEDS

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

Delineating Populations

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

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

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

Population Resiliency

For the dwarf-flowered heartleaf to maintain viability, its populations or some portion thereof must be resilient. Stochastic factors that have the potential to affect dwarf-flowered heartleaf include impacts to its habitat, particularly human development pressures, but also climate change and presence of invasive species. Other factors that influence the resiliency of dwarf-flowered heartleaf populations include abundance within populations, and habitat factors such as 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).

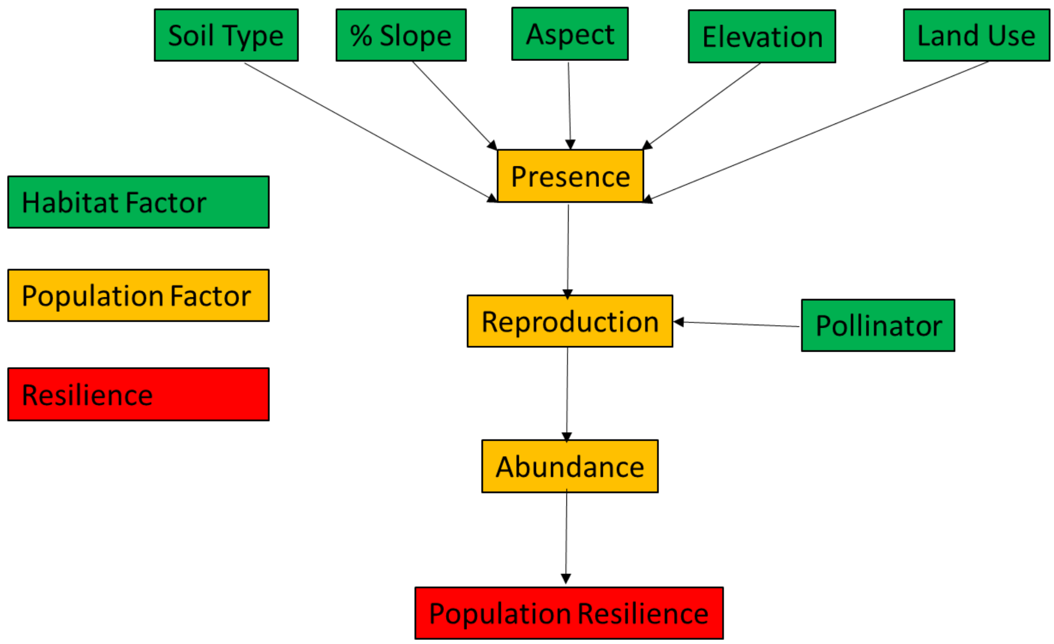


Figure 3.1. Conceptual diagram describing population and habitat factors influencing population resilience for dwarf-flowered heartleaf.

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

In a site suitability model generated with habitat rankings from 5 (the most suitable) to 36 (least suitable habitat) across 7 rank classes, the most common classification included the following microhabitat elements: the slope aspect was north-facing, soil type is Pacolet sandy loam, elevation was between 230-260m, percent slope is 8-10%, and land use is deciduous forest (Table 3.1; Wagner 2015). More importantly, populations found in areas with a percent slope greater than 28, or elevation less than 199 m or greater than 415 m, are unlikely to be dwarf-flowered heartleaf. Slope aspect analysis shows that *H. naniflora* has already adapted to the cooler, wetter conditions of north facing slopes suggesting that this species would fare poorly under climate change scenarios predicting warmer and drier environments (mimicking south facing slopes) throughout their range, supporting a similar claim from Warren (2008).

Table 3.1. Frequency of element occurrence records (EORs) for each habitat variable. For continuous variables (slope and elevation) data were grouped into classes with the value shown being the top end of the range. * indicates most common classification for that habitat variable.

slope		land use (LU)		soil		elevation		aspect	
% slope	EORs	LU type	EORs	soil code	EORs	Elev. (m)	EORs	aspect	EOR
5.5	20	open water	1	6*	123	<199	0	N*	57
8	50	Low intensity residential	14	7	59	229.8571	34	NE	32
10.5*	54	High intensity residential	3	10	1	260.7143*	65	NW	32
13	35	Commercial/ Industrial	1	11	8	291.5714	29	E	13
15.5	22	Deciduous Forest*	153	other	0	322.4286	34	W	10
18	10	Evergreen Forest	13			353.2857	24	SE	22
20.5	3	Mixed Forest	1			384.1429	10	SW	13
23	3	Grassland	3			415	4	S	20
25.5	0	Pasture	11			More	0		
28	2								
>28	0								

Reproduction and Presence of Pollinators

The pollination of Hexastylis has not been well studied but the genus is thought to be pollinated by insects including flies, wasps, and thrips (Otte 1977). Additionally, Lengyel et al. (2010) described how, within the family Aristolochiaeae, more than 50% of the plant lineage is myrmecochorous (seed dispersal via ants). This supports Gaddy's work (1986), which found three species within the Hexastylis Heterophylla subgroup (*H. heterophylla, H. naniflora, and H. minor*), which employ myrmecochory as a method for seed dispersal.

Because the flower for this species is oftentimes partially or completely covered with soil and leaf litter, possibly inhibiting pollinator activity (Gonzalez 1972), there is still uncertainty in the pollination mechanism for dwarf-flowered heartleaf. Otte (1977) suggests that a variety of possible pollinators reside in this leaf litter, however, the calyx opening is considered to be far too small for efficient pollinating (Gaddy 1981). There are, however, invertebrates within this proposed size limit that could theoretically act as pollinators. It is possible that the species employs self-pollination, with or without a vector, or that cross-pollination occurs by a number of invertebrates. Jones et al. 2014 investigated pollination of dwarf-flowered heartleaf under a manipulative experimental design, and found that while insects may play a significant role in pollination, even without them, flowers managed to produce a partial seed set. However, two points need to be considered here. First, although flowers managed to produce seeds in the absence of insect pollinators, the efficiency of pollination decreased by almost 50%. Also, even if successful pollination occurs in the absence of insect vectors, the dispersal of plants amongst populations would be limited, and could result in decreased resilience due to genetic concerns such as limited gene flow and issues associated with potential inbreeding depression.

Abundance

The influence of stochastic variation in demographic (reproductive and mortality) rates is much higher for small populations than large ones. Stochastic variation in demographic rates causes small populations to fluctuate randomly in size. In general, the smaller the population, the greater the probability that fluctuations will lead to extinction. There are also genetic concerns with small populations, including reduced availability of compatible mates, genetic drift, and inbreeding depression. Small populations of dwarf-flowered heartleaf have low resilience, leaving them particularly vulnerable to stochastic events.

As of 2016, the combined databases of the NCNHP and SCNDNR contain 239 Element Occurrence Records (EORs) for *H. naniflora* (NCNHP2016, SCDNR 2016). These EORs depict roughly 113 locations which are sufficiently geographically distinct to be regarded as proxies for populations of the species (See *Delineating Populations*). Thus, the total number of populations has increased more than four-fold (from 24 to 113) since the species was listed in 1989.

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

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

There are, however, 13 populations (12% of all known) that are simply known to be extant, with no available estimate of population size (NCNHP 2016, SCDNR 2016). If the most recent population estimates for each EOR are compiled across years of observation, the 113 populations could conservatively be estimated to contain a collective total of more than 300,000 rosettes (NCNHP 2016, SCDNR 2016).

Population Trends

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

Based on the results of the five-year monitoring efforts completed in 2016, nine out of thirteen populations remain stable during the five years of data collection (Robinson and Padgett 2016). The largest known population, Broad River: Henson's Creek, Brice, & Sandy Mush Outcrop in Rutherford County, NC, is estimated to have over 100,000 rosettes (Robinson and Padgett 2016).

This large population consists of many scattered subpopulations on private property; two of the subpopulations are protected as a Registered Heritage Area, although Registry is a non-binding agreement with landowners that can be cancelled at any time (NCNHP 2018).

Two of the thirteen populations increased in numbers from 2012-2016: Cliffside Steam Station and Broad River: Floyds Creek, Long Branch. The Cliffside Steam Station is protected with a voluntary agreement with Duke Energy and was estimated to contain over 39,000 rosettes in 2016. The Broad River: Floyds Creek, Long Branch population is not at all protected, but was 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 short-term 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 113 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 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.

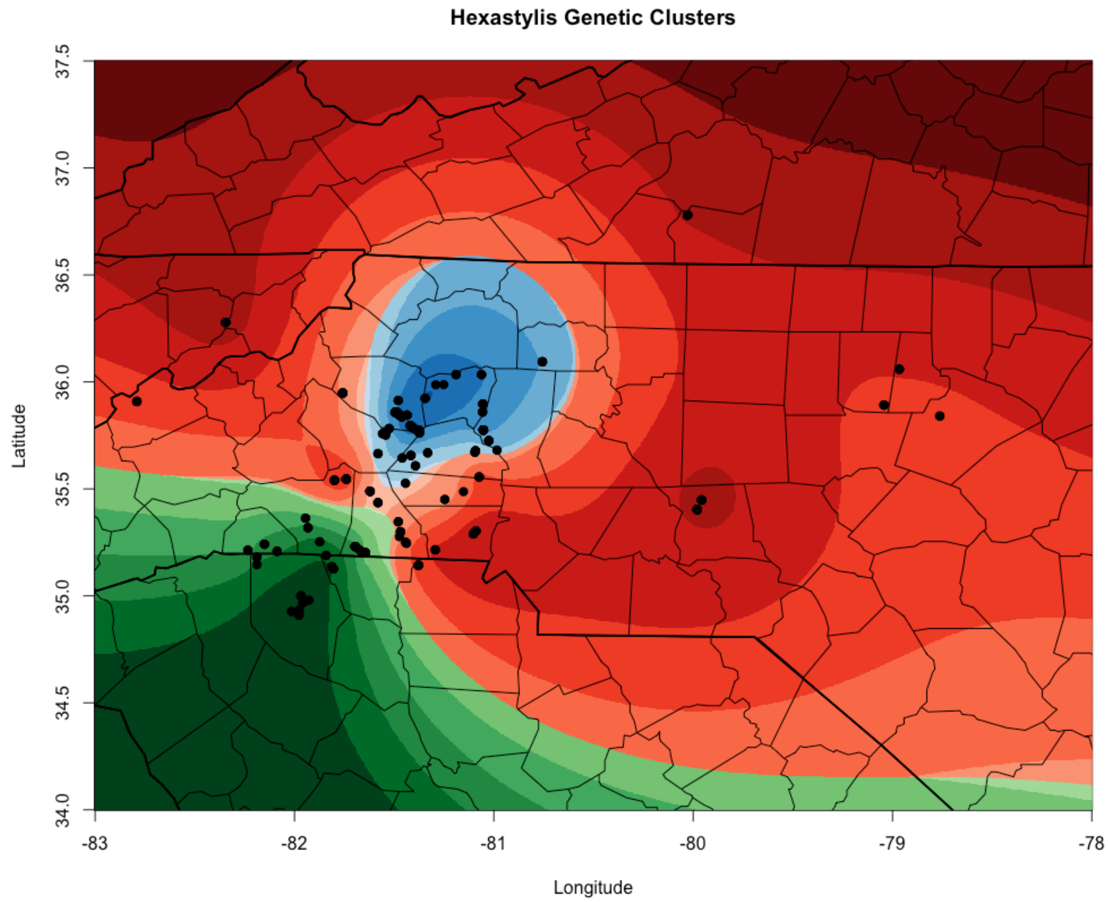


Figure 4.1. Recent genetic analyses detailing clustering of the genus Hexastylis. Green areas represent "true" *H. naniflora*; Blue represents a possible new species; Red represents other species in the genus (*H. minor, H. heterophylla*, etc.).

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 of years since the species was last observed at a given location (1964-2017), so although recent reports suggest the species consists of 113 populations, some of that data is fairly outdated. For the purposes of this SSA, we only used EOs that were observed since 2005. We did this for several reasons. First, we did not want to go back too far and assume a population was still present. Second, we wanted to be consistent in what we considered "current" for both categorizing resilience and use in the habitat model (discussed later). Also, experts concurred that records as old as 12 years are still likely to persist. Finally, there was a natural break in the data at the year 2005, where most detections before this year, were quite a bit older (i.e. 20 years old). It is important to note that many of the populations that we excluded from our analysis may still persist on the landscape. In fact, many EOs for this species have persisted for decades, despite not having intervening surveys to confirm their persistence. Despite this, we are being conservative in our assessment, and have decided to implement the 2005 cutoff for record data.

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

To determine overall resilience for populations, we used EO viability ranks and expert opinion to bin population size classes into corresponding resilience categories. EO viability ranks for the species include excellent, good, fair, poor, extant, historical, and failed to find. The primary factor in determining these ranks is EO size (as quantified by number of clumps). Condition of habitat (vegetation community and structure) and landscape context (extent of suitable habitat and physical factors) are also incorporated secondarily. Appendix 2 shows the NCNHP EO rank specifications for dwarf-flowered heartleaf. The EO rank specifications suggest good-excellent viability for populations consisting of at least 500 individuals, given there is sufficient high quality habitat; fair viability for populations consisting of 100-500 individuals, depending on habitat conditions; poor viability for populations consisting of less than 100 individuals. Recent reports (NCNHP 2016a; NCNHP 2016b) focus monitoring studies on populations with greater than 1,000 individuals, populations that are assumed to be very viable. Because we do not have habitat level information for every population we assessed, we synthesized all of the 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, and moderate-high probability of extirpation for 20-30 years at or above the current population size.

Occupancy and Abundance

There are 78 populations of dwarf-flowered heartleaf that have been observed within the last 10 years (Table 4.1), and resilience of these populations is as follows: 28 (very high); 5 (high); 26 (moderate); 19 (low). Table 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.

Site Name	State	County	Last Observed	Total plants	Resilience
Glade Creek, Alex County	North Carolina	Alexander	2017	>1000	very high
Catawba River: Hoyle Crk-Micol Crk	North Carolina	Burke	2013	>1000	very high
Island Creek Heath Bluff	North Carolina	Burke	2016	>1000	very high
Gunpowder Creek: South of Hudson	North Carolina	Caldwell	2012	>1000	very high
Peaked Top Rare Plant Site/Foothills Landfill	North Carolina	Caldwell	2014	>1000	very high
Jacob Fork West Corridor	North Carolina	Catawba	2012	>1000	very high
Murrays Mill/Upper Balls Creek NA	North Carolina	Catawba	2013	>1000	very high
NCDOT TIP: R-2824	North Carolina	Catawba	2015	>1000	very high
South Fork Catawba R: Clark Crk, Miller Br, Cata Mem Hos	North Carolina	Catawba	2013	>1000	very high
Cowpens NBF - Site 1	South Carolina	Cherokee	2016	>1000	very High
Cliffside Steam Station	North Carolina	Cleveland/Rutherford	2016	>1000	very high
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	>1000	very high
Broad River: Brushy Creek	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Kings Mountain Res	North Carolina	Cleveland	2016	>1000	very high

Buffalo Creek: Tributaries N and S of SR 2047	North Carolina	Cleveland	2012	>1000	very high
Rhyne Conservation Preserve	North Carolina	Lincoln	2016	>1000	very high
Mill Creek Forest and Seep	North Carolina	Polk	2016	>1000	very high
New Hope Springhead Swamp	North Carolina	Polk	2016	>1000	very high
Big Horse Creek Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Broad River: Floyds Creek	North Carolina	Rutherford	2016	>1000	very high
Davenport Road/Mountain View Rare Plant Site	North Carolina	Rutherford	2016	>1000	very high
Facebook Site	North Carolina	Rutherford	2016	>1000	very high
Floyds Creek Tributray Rare Plant Site	North Carolina	Rutherford	2012	>1000	very high
New Bethel Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Richardson Creek trib above Toms Lake	North Carolina	Rutherford	2016	>1000	very high
DNR Peters Creek Heritage Preserve	South Carolina	Spartanburg	2016	>1000	very high
Taylor Blalock Res	South Carolina	Spartanburg	2016	>1000	very high
Leepers Creek Heartleaf Site	North Carolina	Lincoln	2006	>1000	very high
Little Gunpowder Creek Rare Plant Site 1	North Carolina	Caldwell	2015	500-1000	high
Little Gunpowder Creek Rare Plant Site 2	North Carolina	Caldwell	2015	500-1000	high
Northern Catawba County	North Carolina	Catawba	2017	500-1000	high
Rock Barn Solar Farm	North Carolina	Catawba	2010-2011	500-1000	high
Buffalo Creek Rare Plant Site	North Carolina	Cleveland	2012	500-1000	high
Third Creek Rare Plant Site	North Carolina	Alexander	2010	100-500	moderate
Hickory Area	North Carolina	Burke/Catawba/Caldwell	2016	100-500	moderate
Burke County - Drowning Creek UT	North Carolina	Burke	2017	100-500	moderate
Simms Hill/Little River Uplands	North Carolina	Burke	2015	100-500	moderate
Smith Cliff/Henry Fork River	North Carolina	Burke	2015	100-500	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork Catawba River Jacobs Fork and Camp Creek	North Carolina	Catawba	2016	100-500	moderate
NCDOT TIP R-2824	North Carolina	Catawba	2015	100-500	moderate
South Fork Catawba River, Henry Fork	North Carolina	Catawba	2007	100-500	moderate
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	100-500	moderate
Brushy Creek Headwaters	North Carolina	Cleveland	2014	100-500	moderate
First Broad River: Crooked Run Creek	North Carolina	Cleveland	2010	100-500	moderate
No Business Creek, Boyd Tract	North Carolina	Cleveland	2007	100-500	moderate
West Shelby Mesic Slope	North Carolina	Cleveland	2016	100-500	moderate
UT of Kings Mountain Res	North Carolina	Gaston	2012	100-500	moderate
Buffalo Shoals Creek	North Carolina	Iredell	2014	100-500	moderate
Cat Square Heartleaf Forest	North Carolina	Lincoln	2012	100-500	moderate
Collinsville (Hughes) Creek Slopes	North Carolina	Polk	2016	100-500	moderate
Fox Knoll Farm	North Carolina	Polk	2016	100-500	moderate
Forest City: Adj to Isothermal CC	North Carolina	Rutherford	2010	100-500	moderate
Jonas Road Rare Plant Site	North Carolina	Rutherford	2014	100-500	moderate
Knob Creek NA	North Carolina	Cleveland	2005	100-500	moderate
Buffalo Creek	North Carolina	Cleveland	2005	100-500	moderate
Kross Keys NA	North Carolina	Polk	2005	100-500	moderate
Catawba River: North Fork Mountain Creek	North Carolina	Catawba	2005	100-500	moderate
Catawba River: Lake James	North Carolina	Burke	2006	100-500	moderate

Hogpen Branch Transplant Site	North Carolina	Rutherford	2005	100-500	moderate
NCDOT TIP R-3603A	North Carolina	Alexander	2017	<100	low
South Mountains Pleasant Grove Uplands	North Carolina	Burke	2016	<100	low
Gunpowder Creek	North Carolina	Caldwell	2012	<100	low
Killian Crossroads	North Carolina	Catawba	2010	<100	low
Pott Creek	North Carolina	Catawba	2012	<100	low
Beaverdam Crk at First Broad River	North Carolina	Cleveland	2011	<100	low
Buffalo Creek: Potts Creek	North Carolina	Cleveland	2012	<100	low
Buffalo Creek: Ravine	North Carolina	Cleveland	2007	<100	low
Hickory Creek - UT (Shelby High School)	North Carolina	Cleveland	2016	<100	low
Boulder Creek Subdivision - Jordan Road	South Carolina	Greenville	2016	<100	low
Gateway Elementary School	South Carolina	Greenville	2017	<100	low
Fanjoy Road Site	North Carolina	Iredell	2015	<100	low
Levan Family Farm	North Carolina	Iredell	2013	<100	low
Lincoln County, SR-1314	North Carolina	Lincoln	2014	<100	low
Northeast Lincolnton: UT Walker Branch	North Carolina	Lincoln	2009	<100	low
Sandy Spring Church Springhead Swamp	North Carolina	Polk	2005	<100	low
First Broad River: Hickory Creek	North Carolina	Cleveland	2006	<100	low
Smith Cliff/Henry Fork River	North Carolina	Burke	2005	<100	low
First Broad River: Beaverdam Creek Tribs	North Carolina	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				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**	**18**	**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: NCNHP 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	Rhyne 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
	NCNHP	Broad River: Henson's Creek, Brice, & Sandy Mush Outcrop (EO099)	106,940	83.39
	NCNHP	Broad River: Cleghorn Creek, US 221 (EO 176)	6,750	7.24
	NCNHP	Cowpens National Battlefield (SC EO 016, 017, 018)	2,823	6.05
	NCNHP	Peters Creek Preserve (SC EO 011)	3,306	8.98
	NCNHP	Blalock Reservoir (SC EO 007, 031)	3,505	7.59
Decreasing	NCNHP	Second Broad River (Forest City Industrial Complex) (EO 154)	2,576	4.74
	NCNHP	South Fork Catawba River: Jacob Fork, Camp Creek (EO 158)	123	0.09

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

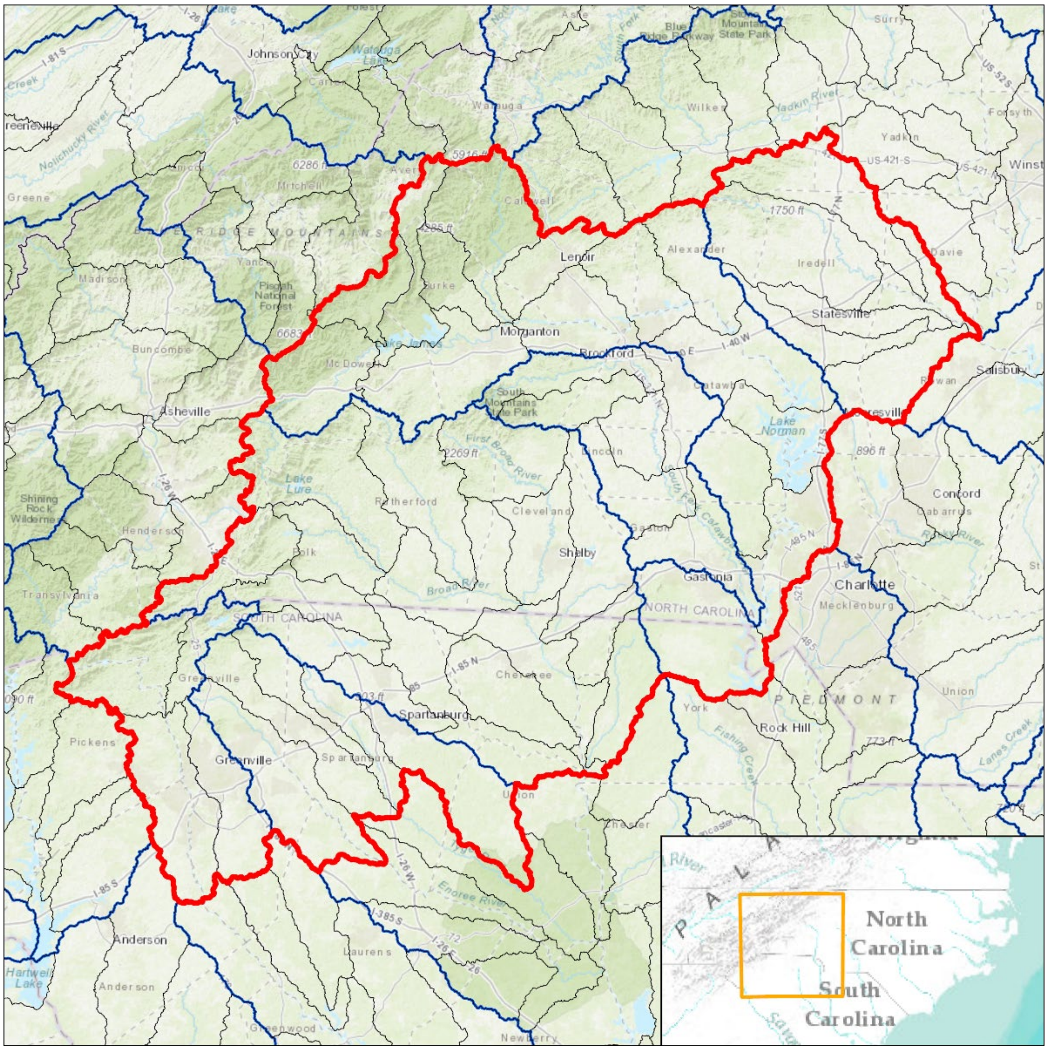
A previous habitat suitability study attempted to quantify the habitat requirements for dwarf-flowered heartleaf. A model was created to predict habitat suitability, and based on the model results, the strongest habitat correlations were slope, aspect, soil type, elevation, and land use (Wagner 2015). With this model in mind, 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.

<u>Source Data and Model Variables</u>

Fifty three, 10-digit hydrologic units (HUC) comprise the analysis extent (Figure 4.2). 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. North Carolina EO data were in polygon format whereas South Carolina EO data were points, and these were digitized at a scale that accurately identified the boundaries of the individual population areas. 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 4.2. 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 (Philips 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, aspect 5-class, slope, solar radiation, and maximum annual temperature. It is interesting to note that the previous habitat model discussed in Wagner (2015) 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.

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 4.3 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 predictions to focus on the typical habitat conditions for this species. The total area ranked greater than 0.39 in the Maxent model was just 6.00% of the total analysis area (Table 4.4).

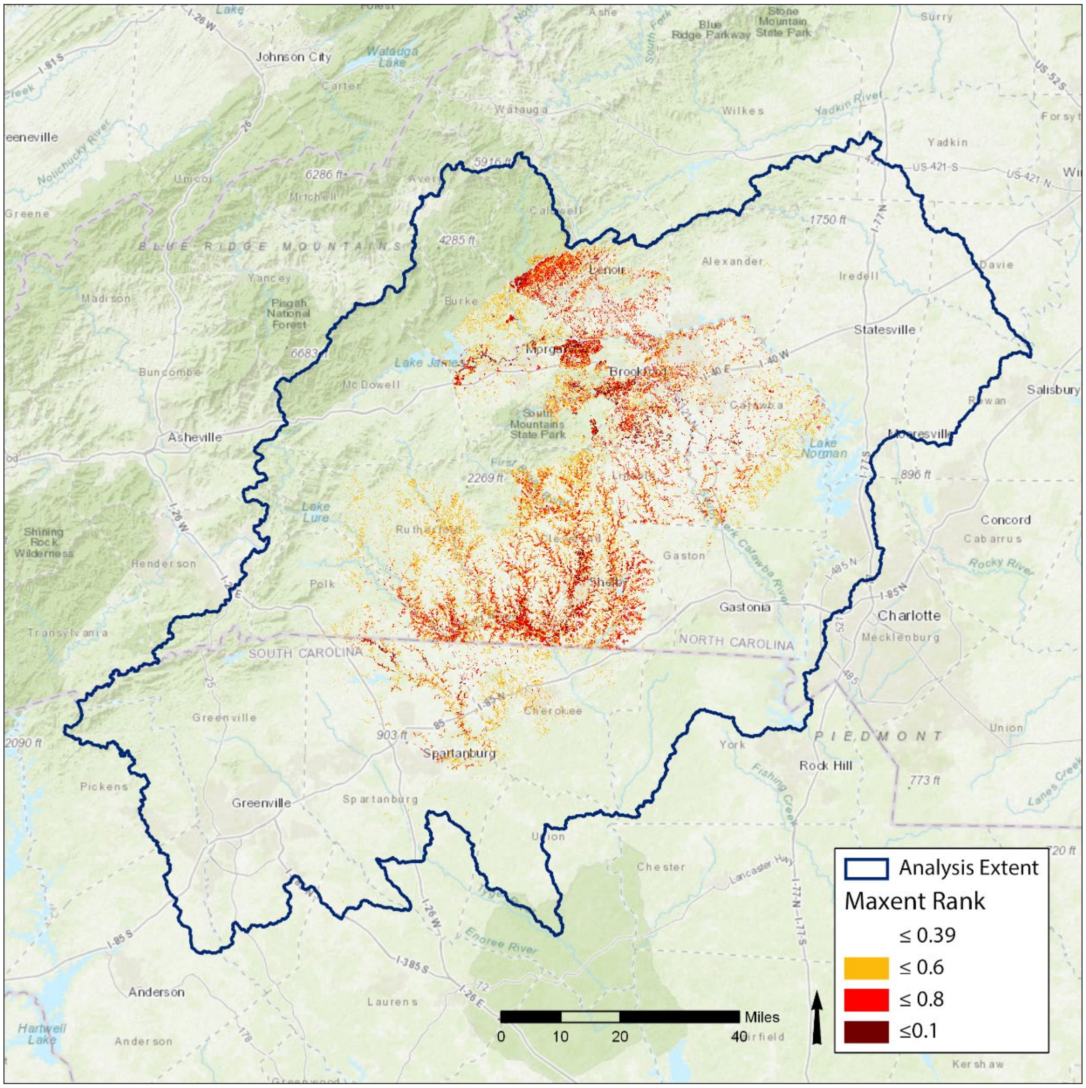


Figure 4.3. Maxent model output map

Table 4.4-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%

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

The Maxent output supplies estimates of the relative contributions of the environmental variables to the Maxent model (Table 4.5). SSURGO mukey (Map Unit Key) is the top contributing variable. One hundred and thirty-five individual soil types are present within the polygon boundaries of the *Hexastylis naniflora* element occurrences. Many of these individual soil types are part of soil complexes and are separated by things such as percent slope, erosion, how stony/rocky, and amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25 to 60 percent slopes, very stony (14.1% of total). However, collectively the Meadowfield soils only comprised 14.3% of all soils). The individual Pacolet soil types were very common and collectively comprise 36% of all soil types present. Woolwine, Rion, and Fairview soils were also collectively common, comprising 10.4%, 9.7%, and 8.8% of all soils present respectively.

Table 4.5. Percent contribution of the environmental variables

Environmental Variable	Percent Contribution
SSURGO mukey	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%

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.

Piedmont forested landcover habitats dominate the land area of the element occurrences. 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 landcover classes, but each at small percentages.

The landcover majority classification scheme reduces the total number of landcover classes present in the analysis extent from 23 to 11. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landcover 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 landcover area representation in the landcover majority layer suggests that many Hexastylis population areas are situated in areas impacted by disturbed landcover. This is likely due to urban encroachment and increasing fragmentation of habitats.

The landcover Hexastylis *naniflora* grouping reveals the amount of disturbance present in Hexastylis population areas. Landcover 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 landcover groupings are all at less than 1% each.

Geomorphons revealed that the majority of Hexastylis element occurrence areas are situated in concave landforms. Geomorphon categories hollow (13%), valley (46%), and depression (10%) collectively comprise 69% of all Hexastylis 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, 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 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 4.6). 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 for low to very high. It appears the model gives us some predictive ability regarding habitat suitability where higher Maxent scores, on average, result in higher population resilience.

Table 4.6-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
Within Groups	28036.3	68	412.30		
Total	32412.0	72			

Current Species Representation

Representation describes the ability of a species to adapt to changing environmental conditions. We lack genetic and ecological diversity data to characterize representation for dwarf-flowered heartleaf. In the absence of species-specific genetic and ecological diversity information, we typically evaluate representation based on the extent and variability of habitat characteristics across the geographical range. However, the dwarf-flowered heartleaf has a very limited range, and after consulting with experts, we decided delineating representative units was not appropriate for this species.

Current Species Redundancy

For the dwarf-flowered heartleaf to maintain viability, the species also needs to exhibit some degree of redundancy. Species-level redundancy reflects the ability of a species to withstand catastrophic events, and is best achieved by having multiple, widely distributed populations relative to the spatial occurrence of catastrophic events. Redundancy for dwarf-flowered heartleaf is the total number and resilience of population segments and their distribution across the species range.

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

As stated previously, there are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years, and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low). The populations are spread across the range, although a majority occur in North Carolina. Although, there appears to be adequate redundancy within the range of dwarf-flowered heartleaf to withstand the impacts of localized press catastrophic disturbances, the species range is very small, making it potentially vulnerable to long-term catastrophic events, such as climate change.

CHAPTER 5: INFLUENCES ON VIABILITY

Hexastylis naniflora populations occur in rapidly growing urban areas with expanding suburbs of Charlotte, NC, to the east; Hickory, NC, to the north; and Greenville and Spartanburg, SC, to the south. At the time of listing, it was determined that the species was most threatened by habitat loss due to the conversion of land to residential, commercial, and industrial use in these areas. In addition to threats associated with residential, commercial, and industrial development, other documented threats include habitat loss from land conversion to agricultural use, timber harvest, hydrological alterations from the damming of ponds, impacts from grazing cattle, ORV damage, trampling from foot traffic, invasive species, highway or road improvements, and erosion or siltation (NCNHP 2016, Robinson and Padgett 2016). Climate change may exacerbate these risk factors through changes in temperature and precipitation.

Threats were assessed for populations monitored by NCNHP during 2012-2016 (Robinson and Padgett 2016), and EOs were reviewed for other documented threats to populations. Indirect or direct threats that were observed, inferred, or suspected to have an impact on populations were recorded and assigned a ranking based on their severity, scope, and immediacy from field observations. The rank for each threat factor determines the overall value for each threat observed at each population. No significant changes in threats within populations were noted from 2012-2016. Threats observed during these years included development, incompatible forestry practices, agriculture, trampling, invasive exotic species, sedimentation, erosion, and road construction.

Below, we summarize primary threats to the viability of dwarf-flowered heartleaf. Primary influences will be carried forward in our future projections in the next section.

Human Population Change

Increasing human populations drive development. With increases in population, there will be increasing conversion of open space to more impervious cover, with a subsequent increase in roads and other associated infrastructure. Increases in roads and impervious cover have the potential to lead to habitat loss and/or fragmentation, a primary risk factor for dwarf-flowered heartleaf. Tables 5.1-5.2 and Figures 5.1-5.2 show the estimated human population increases for

North Carolina and South Carolina counties within the range of the species. The most populous counties include Greenville and Spartanburg in South Carolina, and Catawba, Gaston and Iredell counties in North Carolina.

Table 5.1-Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

County	2018	2023	2028	2033	2037
Alexander	38609	39,244	39,686	39992	40169
Burke	90865	93,124	95,382	97644	99452
Caldwell	83919	86,723	88,689	91126	92870
Catawba	157424	159,799	162,175	164549	166447
Cleveland	98862	99,685	100,004	100128	100170
Gaston	221112	227,667	237,344	245276	252388
Iredell	179740	195,623	211,501	227383	240088
Lincoln	84494	91,034	96,865	103069	107858
Polk	21273	21,823	22,288	22681	22955
Rutherford	67880	68,154	68,283	68341	68368

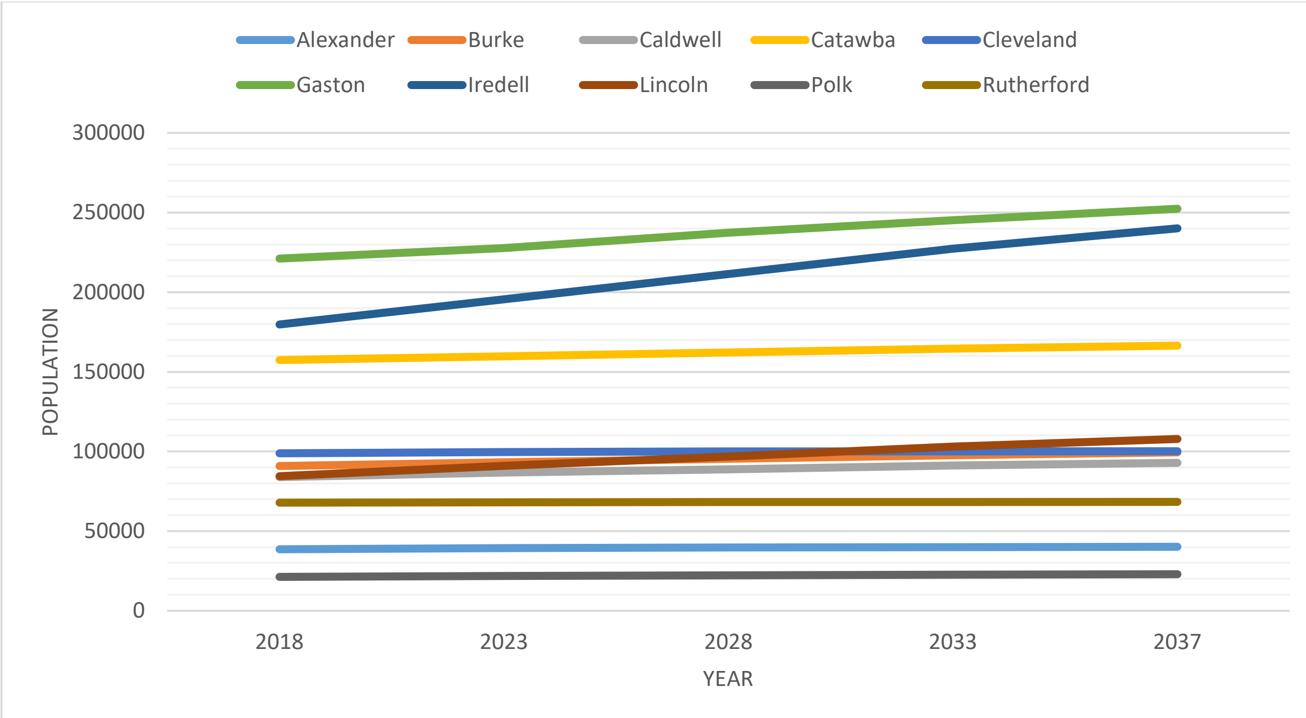


Figure 5.1- Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

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
Greenville	492,890	517,740	542,290	567,010
Spartanburg	310,220	323,550	336,810	350,110

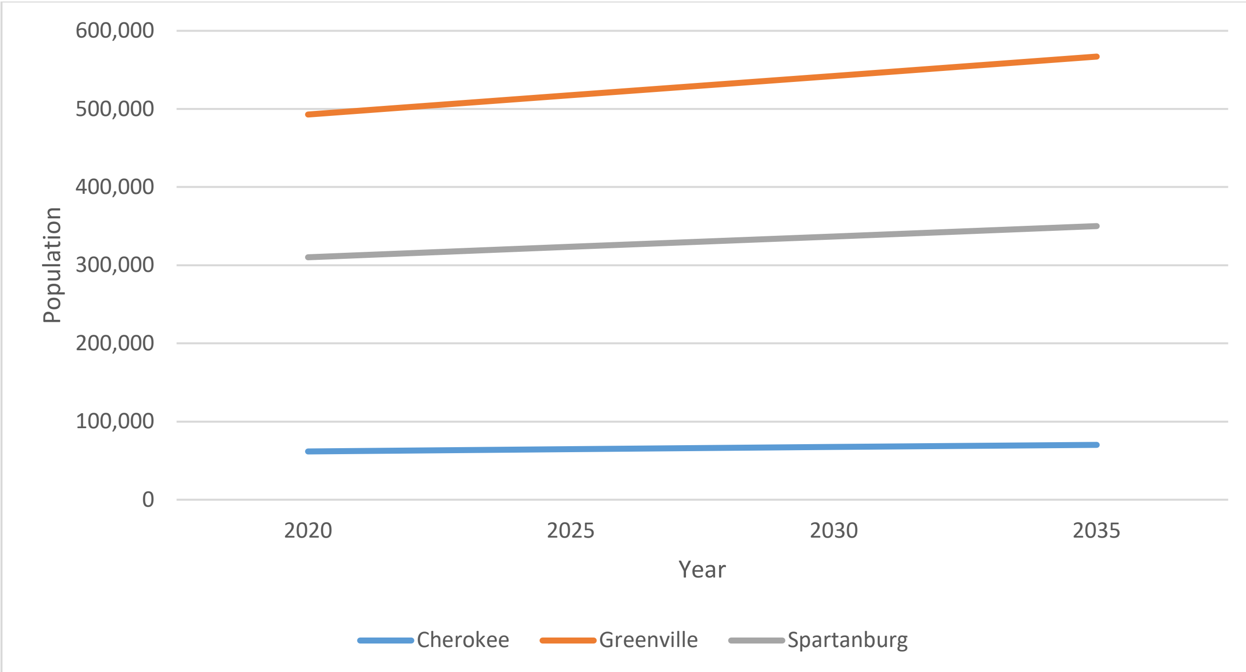


Figure 5.2. Human population projections for South Carolina counties within the range of dwarf-flowered heartleaf. *Source: U.S. Census Bureau, 2000 Census and 2007 Population Estimates. Population projections calculated by South Carolina Budget and Control Board, Office of Research and Statistics.*

Development

A large number of the known populations occur near expanding urban areas and are threatened by the residential, commercial, and industrial development associated with this growth. Populations occurring in more rural areas are threatened by habitat alteration or loss from land conversion to pasture or other agricultural uses, cattle grazing, intensive timber harvesting, residential construction, and construction of small ponds.

A 2011 review of existing NHP EOR data revealed that all or portions of 26 populations (24% of the total) had been directly or indirectly impacted through development projects or other causes such as trash disposal, expansion of residential lawns, cattle, or invasive exotics (NC NHP 2010; SCDNR 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 foreseeable within 42 of the 108 populations (corresponding to 39% of all known populations).

Of these 42 populations, all or portions of 22 (50%) had been adversely impacted by activities requiring ESA Section 7 consultation with the USFWS. The fact that nearly 20% of all known populations had been subject to formal Section 7 consultation illustrates the threats faced by the species.

The most recurrent source of habitat destruction, and certainly the most common trigger for Section 7 consultations involving *H. naniflora* is road and bridge improvement projects. Ten of the 27 largest populations (containing more than 1,000 rosettes) have been the subject of Section 7 consultations between the USFWS and the NCDOT. Collectively, these projects have adversely impacted or are currently expected to impact some 22,135 rosettes. In most cases the Section 7 process has resulted in avoidance or minimization of adverse effects through relocation of plants and/or commitments of on-site protection to those plants remaining (post-construction) within NCDOT right-of-way (ROW).

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 consultations with the USFWS. Examples of these activities include the maintenance or expansion of hydroelectric and drinking water reservoirs, construction of an industrial development complex, and maintenance activities (in compliance with Federal Aviation Administration standards) at a regional airport. Collectively, these activities have involved the loss or relocation of several thousand rosette.

Blalock Reservoir in Spartanburg County, South Carolina was once estimated to contain the largest population of *H. naniflora*, with over 11,000 rosettes reported here in 1997 (JJ&G, 1998). This population was the subject of a section 7 consultation as a result of a proposal to raise the elevation of Blalock Reservoir, which provides water supply storage to Spartanburg County and the City of Spartanburg (USFWS, 2001). Approximately one-third of this population was directly threatened by inundation, and the Federal agency committed to the relocation of some 3,054 rosettes to remaining areas of occupied habitat around the reservoir. At the conclusion of formal section 7 consultation, the USFWS anticipated that as many as 6,619 rosettes (assuming that all transplants survived) would be afforded protection through restrictive covenants placed on properties owned by the Spartanburg Water System (SWS) surrounding Blalock Reservoir. However, this population was last reported to contain a mere 1,400 rosettes (Newberry, 2006), and has twice since been impacted by encroachments from adjacent landowners (Newberry, 2009; Schneider, 2006, and JJ&G, 2006). Some of these apparent declines could be partially an artifact of incomplete survey effort, in that the exhaustive surveys which led to the 1997 estimate (of 11,000 rosettes) have never been repeated. However, it seems unlikely that plants occurring on privately owned shoreline not subject to restrictive covenants would be any more stable than those occurring on properties specifically protected and managed for the species (by SWS).

Invasive Species

Several of the known populations of dwarf-flowered heartleaf occur on steep ravine slopes which also support stands of mixed hardwoods with an understory of mountain laurel (*Kalmia latifolia*) or *Rhododendron spp*. These stands are often very dense and reduce the amount of light reaching the dwarf-flowered heartleaf plants growing below. Under these conditions the plants often show reduced vigor and reduced flower and fruit production. Careful, selective logging or natural tree fall and limited understory removal would open up these populations to more light. Additional light, if not accompanied by increased siltation from the intensive soil disturbances associated with forest clear-cutting, probably would benefit these populations (Gaddy 1981).

Invasive exotic plant species are rampantly spreading throughout riparian corridors and ravines across the range of this species. Invasive exotics such as English Ivy (*Hedera helix*), Chinese privet (*Ligustrum* spp.), Japanese honeysuckle (*Lonicera japonica*) and Japanese Nepal grass (*Microstegium vimineum*) are known to threaten several populations; however, the scope and magnitude of this threat has not been comprehensively assessed. This threat requires active management in order to be successfully abated. At present, the majority of protected populations are secured against habitat conversion, but lack designated managers with the technical expertise and available resources (funding and personnel) to address this threat.

Climate Change

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

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

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

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 (NCILT 2012, p.27; IPCC 2013, p.7):

- More frequent drought
- More extreme heat (resulting in increases in air and water temperatures, Figure 5-3)
- Increased heavy precipitation events (e.g., flooding)

- More intense storms (e.g., frequency of major hurricanes increases)
- Rising sea level and accompanying storm surge

In recent years, the Southeast has experienced moderate to severe droughts that many observers have implicated in population declines and poor transplant survivorship (NC NHP, 2010). A wildfire, presumably brought on or at least exacerbated by drought conditions, burned portions of one of the largest known populations in 2009 (Foothills Landfill in Caldwell County; Golder and Associates, 2009). Accelerated climate change is expected to increase the frequency and extent of drought conditions across the southeast (Karl, et al. 2009). The extent to which these climate changes will significantly affect populations of dwarf-flowered heartleaf is currently unknown.

Appendices 4a and 4b gives summary reports on historical and future predicted climate parameters from the USGS National Climate Change Viewer for both North Carolina and South Carolina. As discussed above, the trend for these States is as it is for the Southeast in general: more frequent drought, more extreme heat, and increased precipitation events. If these predictions hold true, dwarf-flowered heartleaf habitat would likely be impacted through increased evaporative rates and decreased soil moisture (Appendices 4a and 4b), increased potential for catastrophic wildfire events, as well as potential disruption of stream bank morphology through increased flooding events.

Chapter 6: FUTURE CONDITION

Future Considerations

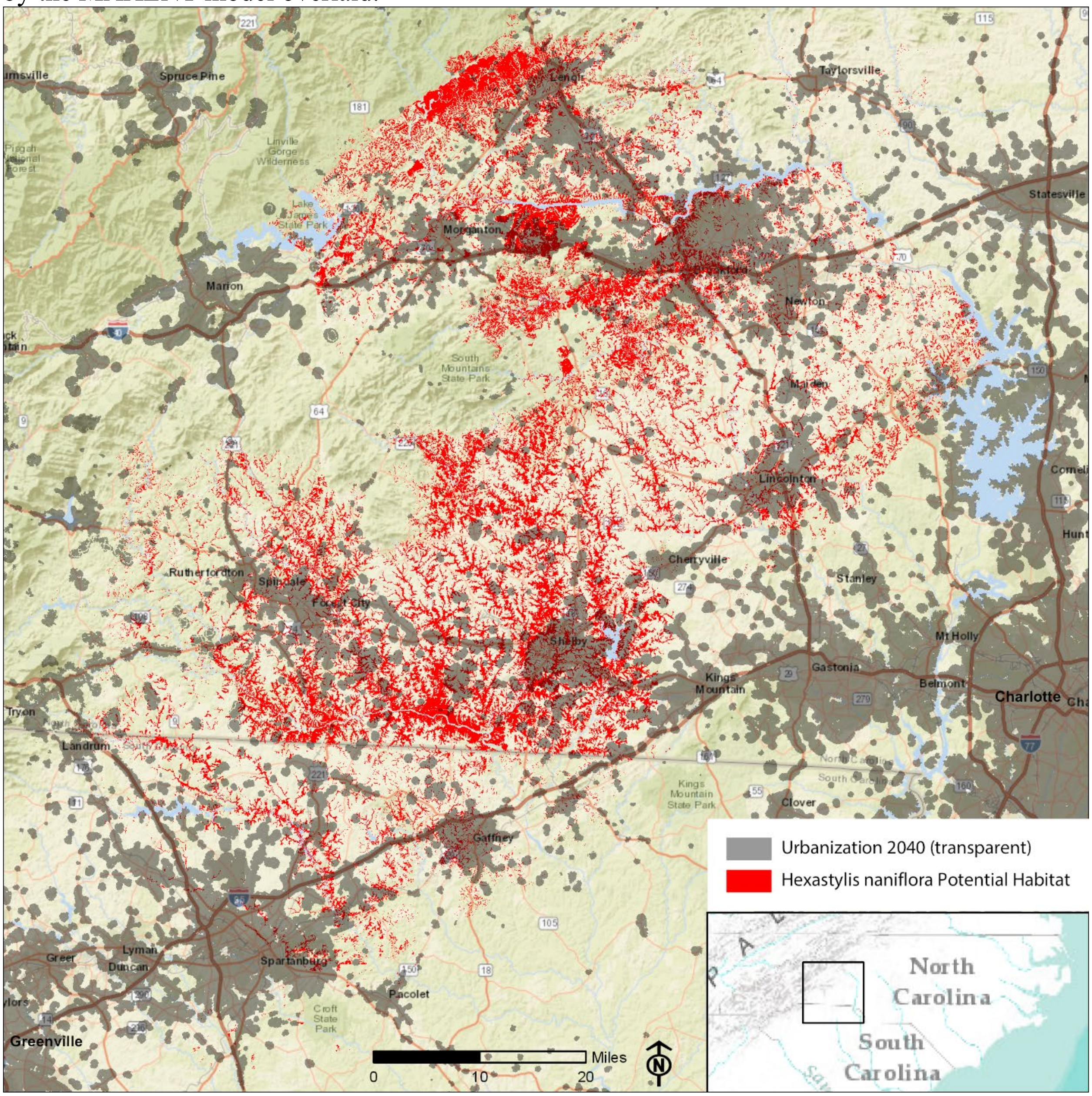
Our analysis of the past, current, and future influences on what the dwarf-flowered heartleaf needs for long term viability revealed that there are several influences that pose risks to future viability of the species. These risks are primarily related to habitat changes from development and long term 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 3 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 Impact. 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, 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 or rediscovery of previously known 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.

We use the Slope, Land cover, Exclusion, Urbanization, Transportation, and Hillshade (SLEUTH) models to determine areas predicted to be urbanized by 2040 (Figure 6.1). SLEUTH is a cellular automata model that applies transition rules to the states of a gridded series of cells, and in this case the transition is that from undeveloped to developed land cover, otherwise known as urbanization (Clarke, 1995), and has been successfully applied worldwide over the last 15 years to simulate land use change.

Figure 6.1. Results of the SLEUTH model with *Hexastylis naniflora* potential habitat predicted by the MAXENT model overlaid.



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—78 populations)
- % increase in projected development (SLEUTH probability of urbanization >80%) within areas delineated as potential habitat by the Maxent habitat model

There is no data available on the exact relationships between urbanization and the impacts to dwarf-flowered heartleaf. We do know that several current populations are located in areas with surrounding urban landscapes. We also know that urban development has led to extirpation of populations in the past through loss of habitat. Because of this uncertainty, we attempted to capture unknowns in two ways. First, our scenarios reflect a range of potential impacts from urban development. Also, we used two thresholds for % increase in urban development to capture potential deleterious effects: 25% and 50%. Our assumptions were that very small increases in development are unlikely to negatively impact populations; development increase of at least 25% of the area of current populations was likely to have some negative impacts; development increase of at least 50% was likely to have significant impacts to populations. We also assume that populations currently on protected lands are likely to see smaller impacts from urbanization compared to those that are not protected, but protection status (perpetuity vs non-perpetuity) matters. For example, Registered Heritage Areas are non-binding agreements with a land owner, and if the land changes ownership, or the owner decides not to continue with the agreement, then the Registry is no longer valid. Appendix 5 shows the protection status of each delineated population which helped to inform our assessment of resilience under each scenario.

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

The first step in identifying additional areas where dwarf-flowered heartleaf is likely to be found in the future, was to identify EOs from populations that were last observed prior to 2005 (i.e. our cut-off for current populations). Once these older EOs were identified, we created a 1,000 meter buffer around the population and calculated a number of useful metrics including the last known abundance estimate (resilience category), Maxent habitat model metrics, and the results of the SLEUTH model to further refine a list of potential sites where the species would likely be found to persist within our 20-25 year projection window. Appendix 6 shows all of the EOs we considered and the corresponding metrics associated with abundance categories, urban development, and habitat scores.

Next, we implemented a set of ranking rules using the data from Appendix 6 to further assess which EOs had a higher likelihood of persistence on the landscape. We used Simple Multi Attribute Rating Technique (SMART) methodology to quantify and implement our ranking rules. Because the metrics of interest vary in data type (i.e. categorical vs continuous) and range of values (i.e. not all continuous variables have the same maximum and minimum), our first step was to normalize all of the data on a scale of 0-100. Normalization techniques allow for aggregation of criteria with numerical and comparable data. We decided to analyze North and South Carolina data separately because the Maxent model predicts habitat differently across state lines due to differences in soil classification. We weighted each variable according to our opinion of the level of contribution each variable had to the probability of persistence of EOs. This resulted in abundance having the highest weight, and habitat and urbanization given relatively similar weighting. The results of the normalization procedure and weighting can be found in Tables 6.1 and 6.2.

Table 6.1. Normalized scores for SMART analysis of North Carolina EOs and weighting scores. Abundance category represents the resilience category for 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_Code	Abundance Category	MAXENT MEAN	MAXENT Percent 0.8 - 1	80% or greater SLEUTH Percent of Total
1	33	52	8	96
5	33	20	3	100
8	0	35	0	93
17	0	89	85	100
18	0	57	51	98
25	0	82	96	64
33	33	50	18	100
48	0	3	0	86
57	33	21	0	6
58	0	70	34	100
64	33	64	55	87
69	33	81	71	77
70	33	62	7	100
72	33	95	92	100
83	33	11	0	87
84	33	1	0	99
89	33	0	11	100
92	33	5	0	65
118	67	71	2	90
151	33	8	0	68
180	33	20	4	100
187	33	18	5	59
188	33	27	0	37
194	100	93	92	78
207	33	49	10	0
230	0	100	100	85
Weights	100	60	20	80

Table 6.2. Normalized scores for SMART analysis of South Carolina EOs and weighting scores. Abundance category represents the resilience category for 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_Code	Abundance Category	MAXENT Average MEAN	Maxent Classified Percent 0.8 - 1	80% or greater SLEUTH Percent Percent of Total
1	33	67	14	100
2	33	2	0	96
4	0	42	3	90
5	33	0	0	36
6	0	0	0	64
8	33	0	0	86
13	0	22	0	0
15	0	0	0	96
19	0	37	0	35
20	33	16	0	0
21	100	15	0	10
22	0	0	0	100
24	0	13	0	97
25	0	44	0	52
30	33	22	0	12
32	33	22	0	7
33	33	5	0	80
34	0	100	100	99
35	0	74	34	47
36	33	18	0	100
37	0	78	66	100
38	100	16	0	63
39	0	18	0	99
40	33	17	0	80
41	0	36	0	13
42	33	9	0	94
43	0	72	0	57
46	0	31	0	4
49	67	26	0	30
50	33	16	0	46
51	0	0	0	65

52	67	0	0	100
53	33	33	0	34
54	33	28	0	9
55	0	12	0	1
56	33	43	0	4
59	33	12	0	83
60	100	53	21	88
Weights	100	60	20	80

To determine a final rank for likelihood of persistence, we calculated a weighted sum by for each EO. We then converted the weighted sum to a final rank value that ranged from 0-100. Finally, we determined the top 10% and 25% percentile ranking for EOs in each state. Table 6.3 summarizes the final ranks and top 10% and 25% percentile ranks for North and South Carolina. We will include the top 10% in the status quo scenario, and the top 25% in the conservation scenario.

Table 6.3. Final Rank Scores for EOs in North and South Carolina. Dark green represents the top 10% of scores, and light green includes the top 25% of scores.

South Carolina

EO_Code	Final Score
60	79
8	62
53	61
55	60
36	56
33	54
39	48
5	45
59	44
13	43
35	42
34	41
49	41
6	39
50	39
46	37
43	35
24	34
2	34
56	33
54	31
52	31
42	31
32	29
15	26
1	24
41	24
37	22
25	22
22	20
21	20
20	20
19	19
30	17
4	12
40	8
51	5
38	3

North Carolina

EO_Code	Final Score
194	91
72	73
118	70
69	61
64	58
70	58
17	58
230	57
33	57
1	55
58	49
5	49
180	48
18	47
25	46
89	44
84	44
83	42
8	37
151	36
187	36
92	34
188	31
48	27
207	25
57	19

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 new populations will be rediscovered throughout the range, and that there will be a range of impacts from urbanization that are related to the percent increase in urban development and whether a population is protected or not. We assessed population resilience under the following assumptions:

- Seven additional populations are rediscovered based on Maxent model metrics, last known abundance category, and total predicted urbanization from SLEUTH modelling
- Potential impacts of urban development based on SLEUTH Model projections focused on current delineated populations:
  - Protected areas
    - 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 exceeds >50% threshold

High Development Scenario

Under the high development scenario, we assume no new populations will be found 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 new populations found or introduced
- 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 rediscovered throughout the range. The range of impacts from urbanization are the same as the Status Quo scenario. We assessed population resilience under the following assumptions:

- Sixteen populations are rediscovered based on Maxent model metrics, last known abundance category, and total predicted urbanization from SLEUTH modelling
- Potential impacts of urban development based on SLEUTH Model projections focused on current delineated populations:
    - Protected areas
        - Protected in perpetuity—no 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 exceeds >50% threshold

Future Resilience

Our focus on future resilience of dwarf-flowered heartleaf is on the potential impacts from urbanization. Table 6.4 shows a summary of currently delineated populations and the predicted urban development to occur within each of the populations. The table only includes those populations that already have some current amount of urban development, or are predicted to have some amount of development occur by the year 2040. Populations not included in this table are not predicted to be urbanized at all, so for the purposes of future analysis, will be assumed to retain the same resilience category as current. For those populations included in the table, we focus on those populations that are anticipated to increase in urbanization beyond a threshold value, depending on the scenario, but thresholds include >25% and >50% increases. Also taken into account is whether or not a population is on protected lands, and if so, whether the population is protected in perpetuity or not. Below is a summary of projected future resilience under each of the three scenarios.

Table 6.4. Results of the SLEUTH model. Included are only those populations that already have some current amount of urban development, or are predicted to have some amount of development occur by the year 2040. Red cells indicate populations that are predicted to increase >50% in urbanization. Orange cells indicate populations that are predicted to increase >25% in urbanization.

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%	99.65%
306	7804.656249	0.00%	15.11%	49.91%	7.83%	0.00%	22.40%	95.24%
208	55360.86786	17.31%	0.00%	0.00%	0.00%	0.00%	82.69%	82.69%
279	1951.661571	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%	0.00%	6.67%	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%
1	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

In the Status Quo scenario, there are predicted to be 80 populations of dwarf-flowered heartleaf on the landscape (Table 6.5). The predicted resilience of the extant populations are as follows:

very high (27); high (6); moderate (23); low (17); and 7 rediscovered populations with an unknown 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 seven new populations predicted to be rediscovered under this scenario, four are in South Carolina, and three in North Carolina. We did not assess resilience for these rediscovered populations, but it is worth mentioning that the last time these populations were detected, resilience was very high (2), high (1), and moderate (4).

Table 6.5. 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/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	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 Tributray 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
Rhyne 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 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
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	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
EO 194 (North Carolina)	n/a	present
EO 72 (North Carolina)	n/a	present
EO 118 (North Carolina)	n/a	present
EO 69 (North Carolina)	n/a	n/a
EO 64 (North Carolina)	n/a	n/a
EO 70 (North Carolina)	n/a	n/a
EO 60 (South Carolina)	n/a	present
EO 8 (South Carolina)	n/a	present
EO 53 (South Carolina)	n/a	present
EO 55 (South Carolina)	n/a	present
EO 36 (South Carolina)	n/a	n/a
EO 33 (South Carolina)	n/a	n/a
EO 39 (South Carolina)	n/a	n/a
EO 5 (South Carolina)	n/a	n/a
EO 59 (South Carolina)	n/a	n/a
EO 13 (South Carolina)	n/a	n/a

High Development Scenario

In the High Development scenario, there are predicted to be 72 populations of dwarf-flowered heartleaf on the landscape (Table 6.6). 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 6.6. 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 Tributray 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
Rhyne 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
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 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
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
Gateway Elementary School	low	low
EO 194 (North Carolina)	n/a	n/a
EO 72 (North Carolina)	n/a	n/a
EO 118 (North Carolina)	n/a	n/a
EO 69 (North Carolina)	n/a	n/a
EO 64 (North Carolina)	n/a	n/a
EO 70 (North Carolina)	n/a	n/a
EO 60 (South Carolina)	n/a	n/a
EO 8 (South Carolina)	n/a	n/a
EO 53 (South Carolina)	n/a	n/a
EO 55 (South Carolina)	n/a	n/a
EO 36 (South Carolina)	n/a	n/a
EO 33 (South Carolina)	n/a	n/a
EO 39 (South Carolina)	n/a	n/a
EO 5 (South Carolina)	n/a	n/a
EO 59 (South Carolina)	n/a	n/a
EO 13 (South Carolina)	n/a	n/a

Targeted Conservation Scenario

In the Targeted Conservation scenario, there are predicted to be 89 populations of dwarf-flowered heartleaf on the landscape (Table 6.7). The predicted resilience of the extant populations are as follows: very high (27); high (6); moderate (23); low (17); and 16 rediscovered populations with an unknown 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 populations predicted to be rediscovered under this scenario, ten are in South Carolina, and six in North Carolina. We did not assess resilience for these new 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 6.7. 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
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 Tributray 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
Rhyne 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 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
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	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

EO 194 (North Carolina)	n/a	present
EO 72 (North Carolina)	n/a	present
EO 118 (North Carolina)	n/a	present
EO 69 (North Carolina)	n/a	present
EO 64 (North Carolina)	n/a	present
EO 70 (North Carolina)	n/a	present
EO 60 (South Carolina)	n/a	present
EO 8 (South Carolina)	n/a	present
EO 53 (South Carolina)	n/a	present
EO 55 (South Carolina)	n/a	present
EO 36 (South Carolina)	n/a	present
EO 33 (South Carolina)	n/a	present
EO 39 (South Carolina)	n/a	present
EO 5 (South Carolina)	n/a	present
EO 59 (South Carolina)	n/a	present
EO 13 (South Carolina)	n/a	present

Viability Summary

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

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

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

Table 6.8. Viability summary for *Hexastylis naniflora* under 3 future scenarios (projected to year 2040) and compared to Current Condition.

	CURRENT	STATUS QUO	HIGH DEVELOPMENT	TARGETED CONSERVATION
VERY HIGH	28	27	27	27
HIGH	5	6	4	6
MODERATE	26	23	25	23
LOW	19	17	16	17
EXTIRPATED	n/a	5	6	5
REDISCOVERED	n/a	7	0	16
TOTAL	**78**	**80**	**72**	**89**

Opportunities for Additional Conservation

Although our scenarios focus on areas where dwarf-flowered heartleaf have been found in the past, the Maxent model identifies a number of areas as high quality potential habitat for the species that falls outside the immediately known occurrence areas. A few of these areas are detailed below (Figure #).

1. West of the city of Lenoir, south of Highway 90/Adako Rd., north of Highway 64 within Caldwell County. This area identifies a large block of potential habitat. This area falls just outside the administrative boundary of the Pisgah National Forest. The bluffs and tributaries along the Johns River are identified as the best habitat, but there is also ample habitat identified along the forested areas of Celia, Husband, Abingdon and Greasy Creeks. The only known occurrence within this area is associated with Abingdon Creek and is under a conservation easement.

2. Henry Fork River bluffs and Tributaries east of Highway 18 within Burke County. A historic element occurrence is present by the Burke County line, but the entire area is identified as good quality potential habitat for the species where forested habitats remain.

3. Southwest corner of Catawba County west of Highway 321. Several disjointed patches of high quality potential habitat are identified in this region associated with the river and creek slopes. Rock Creek, Jacob Fork River, Pott Creek, and their associated tributaries all contain blocks of potential habitat. A number of element occurrences are identified within this area, but additional habitat is identified both upstream and downstream of the known occurrences.

4. Clark, Pinch Gut, Maiden, and Allen Creeks, north of the town of Maiden. The slopes along these creeks all contain quality potential habitat. Known element occurrences are in the general area, but none are situated within the creeks listed in this area.

5. First Broad River North of Highway 74, Rutherford County. Two older element occurrences are located within this area, however, the forested bluffs along the First Broad River and associated tributaries are identified as good quality potential habitat in many additional upstream and downstream areas in this system.

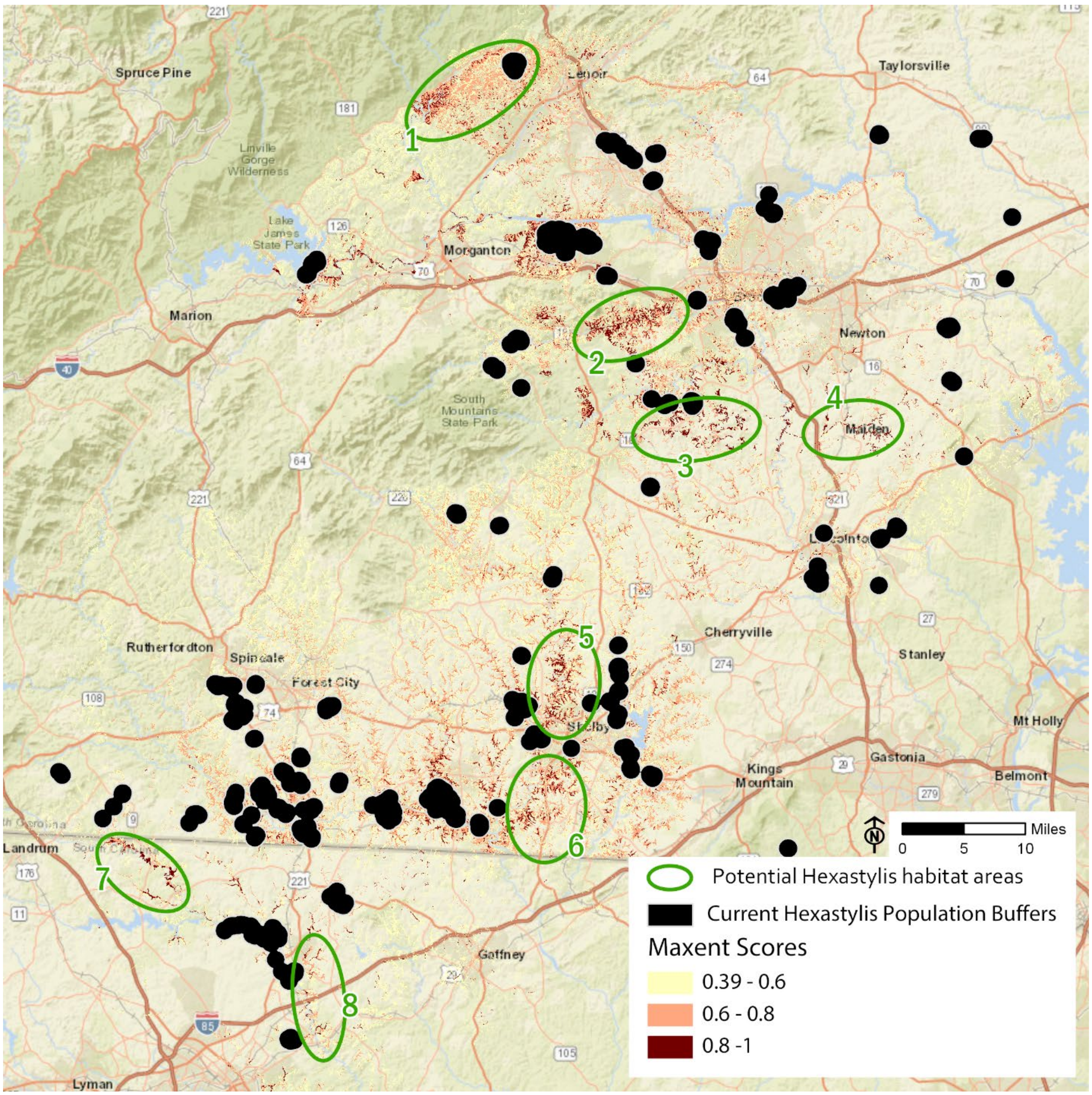
6. Hickory Creek, Sulphur Springs Branch (Little Hickory), Shoal Creek, and tributaries draining into First Broad River South of the Town of Shelby, north of the South Carolina border. The town of Shelby has likely disconnected this site from area 5 listed above. Here, slopes along the creeks and tributaries draining into the First Broad River are identified as potential habitat more so than the slopes along the First Broad River themselves. There in only a single element occurrence known upstream along Hickory Creek.

7. North Pacolet River and Obed Creek, north of where they join. The majority of potential habitat falls along the slopes of the North Pacolet River. Two older element occurrences (1991 last observation) are found in the tributaries draining into the North Pacolet River, and many occurrences are found further upstream. The habitat model suggests that additional undiscovered habitat areas are present.

8. Pacolet River and Island Creek, north of Peters Creek, downstream of the Pacolet River dam. This area displays limited amounts of good quality potential habitat. Recent element

occurrences are present in the upper headwaters of Peters and Zekial Creeks (Zekial Creek drains into Peters Creek) and in areas north of the Pacolet River dam, but none are known along the areas identified in this immediate area.

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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From:	Marshall, Michael E
To:	Mason, Suzanne; Amoroso, Jame; Matt Estep; tpbassette@ncdot.gov; Endries, Mark; Reid, Rebekah N; Becker, Drew N; Stephanie DeMay
Subject:	Re: HENA Drafts
Date:	Monday, April 23, 2018 3:03:41 PM
Attachments:	Combined Appendices.pdf
Importance:	High

And here are the draft appendices to go along with the report itself.

Thanks,

Mike

On Mon, Apr 23, 2018 at 2:59 PM, Marshall, Michael <michael_marshall@fws.gov> wrote:

> Good afternoon all!
>
> It's that time....I've attached a draft of the entire SSA for your review. I'll need to send 2 separate emails; the second email will have the appendices. The attached draft includes all sections you have already reviewed with your comments and suggested edits integrated....and, future conditions, which you will be seeing for the first time. One of the biggest changes we made from the last sections you reviewed was to go back a little further in considering what a current population is....and, focusing on the likelihood that those EOs that we did not include, may very will still persist....you'll see statements to that effect, and how we dealt with this in the "rediscovery" of some populations in 2 of our future scenarios.
>
> As far as when we need your comments....we will need your review sent back no later than COB Monday May 7th. This will ensure that we have adequate time to send out for external peer review before we finalize the report.
>
> Thank you so much for your involvement, and everything you've done for the conservation of the species. We look forward to your feedback!
>
> Take care,
>
> Mike
>
> On Thu, Mar 15, 2018 at 10:26 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:
>
>> Hello all,
>>
>> Just an update and a slight change of course for everyone. We had originally planned on sending out the Future Conditions section for review on March 12th....however, in the interest of not sending you a ton of different materials to review a bunch of times, we've decided to include the Future Conditions in a full draft of the SSA for your next review. That draft will have all of your comments and edits from previous sections integrated into the document, so you'll want to focus your review on the final section (Future Conditions). I anticipate sending that out to the technical team by April 9 (probably a bit earlier), at which point we will ask for your review turn-around to be about 1 week...after we integrate your final edits, we will send out for peer review.

If you have any questions, please let me know.

Thanks!

Mike

On Thu, Feb 22, 2018 at 9:19 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:

> Good morning Team!
>
> Sorry for the delay, but here are the next two sections of the HENA SSA attached for your consideration and review, with appendices attached as well. These sections are Current Conditions and Influences on Viability. As you review and provide comments on these sections, we will be working on the Future Conditions section, which will be the final section of the SSA.
>
> Please provide your edits and comments to these documents in track changes by **COB Friday March 2nd.**
>
> Thanks you so much for your help and input on all of this. And, if at any time you have any questions, please feel free to contact me or Rebekah.
>
> Take care and have a great weekend!
>
> Mike
>
> --
> 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
>
>

--
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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.

--
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Appendix 1

Populations of *Hexastylis naniflora* estimated to contain over 1,000 rosettes in 2010, with updated information in 2016[1], and protection measures for these populations.

Populations known to be afforded some protection are indicated in **bold**.[2]

USFWS population number	State	County	NHP EO numbers (2016)[3]	NHP EO rank (2016)[4,5]	Site	Latest estimate of population size (year)	Estimate of plants on-site protection (year)	Protection comments
1	NC	Burke	029	A	Island Creek Heath Bluff (Lovelady Sites)	50,000+ (2016)	0	Not protected.
2	NC	Burke	178.159-178.161 178.254-178.256 178.280-178.282	A	Catawba River: Love Lady (Hoyle and Micol Creek)	~6,738 (2008-2011)	Awaiting data from NCDOT.	Possible NCDOT protected R-O-W, protection unconfirmed. In early 2016, the Town of Valdese applied to CWMTF to acquire part of this population.
3	**NC**	**Caldwell**	**227**	**A**	**Peaked Top Rare Plant Site (Foothills Landfill)**	**16,463 (2014)**	**16,463 (2014)**	**Conservation Easement (Foothills Conservancy of NC).**
4	**NC**	**Caldwell**	**044**	**AB**	**Little Gunpowder Creek Rare Plant Site 1**	**2,707 (2015)**	**2,424 (2015)**	**DOT mitigation site.**
5	NC	Catawba	158	D	South Fork Catawba River: Jacob Fork, Camp Creek	123 (2016)	27 (2015)	Some plants occur within an undetermined acreage within NCDOT R-O-W (Bassette 2016). Protection unconfirmed.
6	**NC**	**Catawba**	**243.012,** 243.242 243.269, **243.270**	**A**	**Catawba Wildlife Club**	**1,000-1300 (1995-2007)**	**>1,000 (1995-2007)**	**Catawba County Wildlife Club Registered Heritage Area (EO 12) The Nature Conservancy Conservation Easement (EO 270).**
7	NC	Catawba	031	C?	US 321, southeast Hickory	1,202 (2010)	161 (2010)	161 plants within NCDOT R-O-W (Bassette 2016).
8	**NC**	**Catawba**	**96.184,** 96.038 96.039	**A**	**Murrays Mill/Upper Balls Creek**	**~9,150 (2005)**	**11,860 (2013)**	**Fee title by NCDOT (~34 acres).**
9	**NC**	**Cleveland**	100.014, **100.049, 100.050, 100.051, 100.073, 100.074 100.149, 100.233**	**A**	**Broad River/Sandy Run Natural Areas (aka "Broad River Tract")**	**~33,500 (2001-2015)**	**32,702 (2015)**	**Fee title by Broad River Greenway (1,000 acres).**

USFWS population number	State	County	NHP EO numbers (2016)[3]	NHP EO rank (2016)[4,5]	Site	Latest estimate of population size (year)	Estimate of plants on-site protection (year)	Protection comments
			100.236, 100.237 **100.238, 100.239 100.240, 100.241,** 100.246					
10	NC	Cleveland	208	A?	Buffalo Creek: Potts Creek	3,572 (2007)		Awaiting verification that plants are protected in NCDOT R-O-W. Protection unconfirmed.
11	NC	Cleveland	211.072, 211.194		First Broad River: Hop-Hornbeam Natural Area	1,965 (2000)		Awaiting verification that plants are protected in NCDOT R-O-W. Protection unconfirmed.
12	NC	Cleveland	214.201, **214.202, 214.203,** 214.204, **214.205, 214.209,** 214.212, **214.213,**	A	Buffalo Creek: tributaries north and south of SR2047	6,447 (200-2007)		Awaiting verification that plants are protected in NCDOT in R-O-W, bold in EO column. Protection unconfirmed (EO 202, 203, 205, 209, 213).
13	NC	Cleveland	216.028, 216.196, 216.197, 216.198, **216.199, 216.200**	A	Buffalo Creek: Kings Mountain Reservoir	3,310 (200-2016)	~500? (2000-2007) (awaiting updates)	Awaiting verification that plants are protected in NCDOT in R-O-W, bold in EO column. Protection unconfirmed (EO 199, 200).
14	NC	Cleveland	157	AB	First Broad River: Crooked Run Creek	330 (2010)		None of the population is protected within NCDOT R-O-W, determined too far away from roadside, DOT stopped monitoring in 2010 (Bassette 2016).
15	**NC**	**Cleveland/ Rutherford**	**276**	**A**	**Cliffside Steam Station**	**39,545 (2016)**	**~39,545 (2016)**	**Voluntary agreement with Duke Energy; protected acreage unknown.**
16	NC	Lincoln	261.252, 261.259, 261.263	B	Lincoln County Airport and Leepers Creek	7,032 (2005-2006)		Not protected.
17	NC	Polk	023	A	Mills Creek Forest and Seep	1,459 (2016)		Not protected.

USFWS population number	State	County	NHP EO numbers (2016)[3]	NHP EO rank (2016)[4,5]	Site	Latest estimate of population size (year)	Estimate of plants on-site protection (year)	Protection comments
18	**NC**	**Polk**	**125**	**A**	**Broad River: New Hope Springhead Swamp**	**12,235 (2016)**	**1,000-3,000 estimated (2016)**	**New Hope Springhead Swamp Registered Heritage Area (voluntary conservation agreement).**
19	**NC**	**Rutherford**	**154**	**C**	**Second Broad River (Forest City Industrial Complex)**	**2,576 (2016)**	**2478 (2008)**	**Deed restrictions (12 acres). Significant threats from industrial development, invasive exotics, erosion, sedimentation in a fragmented landscape.**
20	**NC**	**Rutherford**	99.009, 99.010, 99.037, 99.052, 99.053, 99.055, 99.061, 99.063, 99.075, **99.076,** 99.079, 99.090, 99.121, **99.172,** 99.181, 99.182, 99.249-.251, 99.267, 99.268	**A**	**Broad River: Hensons Creek Ravine, Brice Rare Plant Site, Sandy Mush Outcrop**	**106,940 (2016)**	**~200-250 (2007-2012)**	**Parris Heartleaf Registered Heritage Area (voluntary conservation agreement on subEO 076 and 172).**
21	NC	Rutherford	176.167-176.170	A	Broad River: Cleghorn Creek Tributary/US221	6,750 (2016)		Not protected.
22	NC	Rutherford	177.016, 177.107, 177.122, 177.063, 177.164, 177.165, 177.166	A	Broad River: Floyds Creek, Long Branch	12,687 (2008-2016)		Not protected.
23	**NC**	**Rutherford**	247.013, 247.056, 247.080, **247.106,** 247.114, 247.115, 247.173, 247.174, **247.286**	**A**	**Broad River: Floyds Creek (aka New Bethel Rare Plant Site)**	**~5,480 (2003-2015)**	**4,873 (2015)**	**Tate Conservation Easement (8 acres) (SubEOs 106 and 286).**
24	**SC**	**Cherokee**	**016, 017, 018**	**BC**	**Cowpens Battlefield**	**2,823 (2016)**	**2,823? (2016)**	**National Park Service, National Battlefield.**

USFWS population number	State	County	NHP EO numbers (2016)[3]	NHP EO rank (2016)[4,5]	Site	Latest estimate of population size (year)	Estimate of plants on-site protection (year)	Protection comments
25	SC	Greenville /Spartanburg	002, 004, 024, 032, 033, 036, 038, 039, 040, 041, 042, 049, 050, 054	Various AB-BD	South Pacolet River and tributaries	5,205 (1991-1998)		Not protected.
26	**SC**	**Spartanburg**	**011, 014, 026--028, 047, 048, 057**	**Various AB-BD**	**Peters Creek Heritage Preserve**	**3,306 (2016)**	**3,306 (2016)**	**State Heritage Preserve (194 acres).**
27	**SC**	**Spartanburg**	**007, 029**	**BD, H?**	**Blalock Reservoir**	**3,505 (2016)**	**3,505? (2016)**	**Restrictive covenants (protected acreage unknown); significant threats to remaining population.**
28[6]	**NC**	**Lincoln**	302.046, **302.262**	**A**	**Rhyne Preserve**	**19,880 (2016)**	**19,873 (2016)**	**Rhyne Preserve (fee title by Catawba Lands Conservancy).**

[1]This table was replicated in the same format and populations as Table B.2 from the most recent USFWS five-year Review of *Hexastylis naniflora* (USFWS 2010) for comparison of changes since the time of the five-year review. Populations that are not believed to contain over 1,000 rosettes but were included in the original Table B.2 are included here, but the “NHP EO rank” and in the “Latest estimate of population size” reflects the smaller size.

[2] In the case of partially protected populations, the column “NHP EO numbers” indicates the specific portions of the population afforded protection in bold font.

[3]NHP EO numbers use the following format: Principal EO.SubEO. Only one number is listed if it is a stand-alone principal EO.

[4]NHP EO rank specifications are defined in Appendix B2. In cases involving principal/sub EOs, only the rank for the principal EO is given.

[5] EO ranks with two letters indicate a degree of uncertainty within the range provided (e.g. a rank of “AB” indicates possibly excellent to good viability).

[6]Population that is currently estimated to have over 1,000 rosettes that was not known to be large populations in 2010 have been added to this table.

Appendix 2

NC Natural Heritage Program (NCNHP) Element Occurrence Rank Specifications for *Hexastylis naniflora*

"A" Rank Specifications (excellent viability)
An A-ranked population of *Hexastylis naniflora* should have more than 500 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest.

“B” Rank Specifications (good viability)
A B-ranked population of *Hexastylis naniflora* should have 200-500 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - more than 500 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

"C" Rank Specifications (fair viability)
A C-ranked population of *Hexastylis naniflora* should have 100-200 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - 200- 500 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

"D" Rank Specifications (poor viability)
A D-ranked population of *Hexastylis naniflora* should have fewer than 100 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - less than 200 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

“E” Rank Specifications (extant)
An E-ranked population of *Hexastylis naniflora* is an occurrence that has recently been verified as still existing, but sufficient information for the factors used to estimate viability has not yet been obtained.

“H” Rank Specification (historical)
An H-ranked population of *Hexastylis naniflora* lacks recent field information verifying the continued existence of the occurrence. In the absence of known disturbance and with the habitat still extant, H is generally recommended for occurrences that have not been reconfirmed for approximately 30 or more years.

"F" Rank Specification (failed to find)
An F-ranked population of *Hexastylis naniflora* has not been found despite a search by an experienced observer at a time and under conditions appropriate for the Element at a location where it was previously reported, but the occurrence still might be confirmed to exist at that location with additional field survey efforts. For occurrences with vague locational information, the search must include areas of appropriate habitat within the range of locational uncertainty.

"X" Rank Specification (failed to find)
An X-ranked population of *Hexastylis naniflora* is considered destroyed based on adequate surveys by one or more experienced observers at times and under conditions appropriate for the species at the occurrence location, or other persuasive evidence indicates that the species no longer exists there or that the habitat has been destroyed to such an extent that it can no longer support the species.

"U" Rank Specification (failed to find)
A U-ranked population of *Hexastylis naniflora* cannot be assigned a rank due to lack of sufficient information on the occurrence or the species identification has not been confirmed.

Rank Specifications Justification
The unit of measurement for population size in this species is "clump" (rosette). EO size (as quantified by number of clumps or rosettes) is the primary rank factor. Condition of habitat (vegetation community and structure) and Landscape context (extent of suitable habitat and physical factors) are also incorporated secondarily. The species thrives most in undisturbed habitat. However, disturbed lands, that have been logged, grazed, mown, or converted to pasture, orchards, or tree plantations have been found to support remnant patches of *Hexastylis naniflora*. The extent to which this species can withstand disturbance is unknown. Populations in disturbed habitat are considered at risk, with relatively poor viability (C or D). Care should be taken when estimating population size, as population estimates have been found to vary widely from the number counted in population censuses. Specifications are based on largest known populations and expert opinion (including James Padgett, Carolyn Wells, Misty Buchanan (formerly Franklin), and Brenda Wichmann).

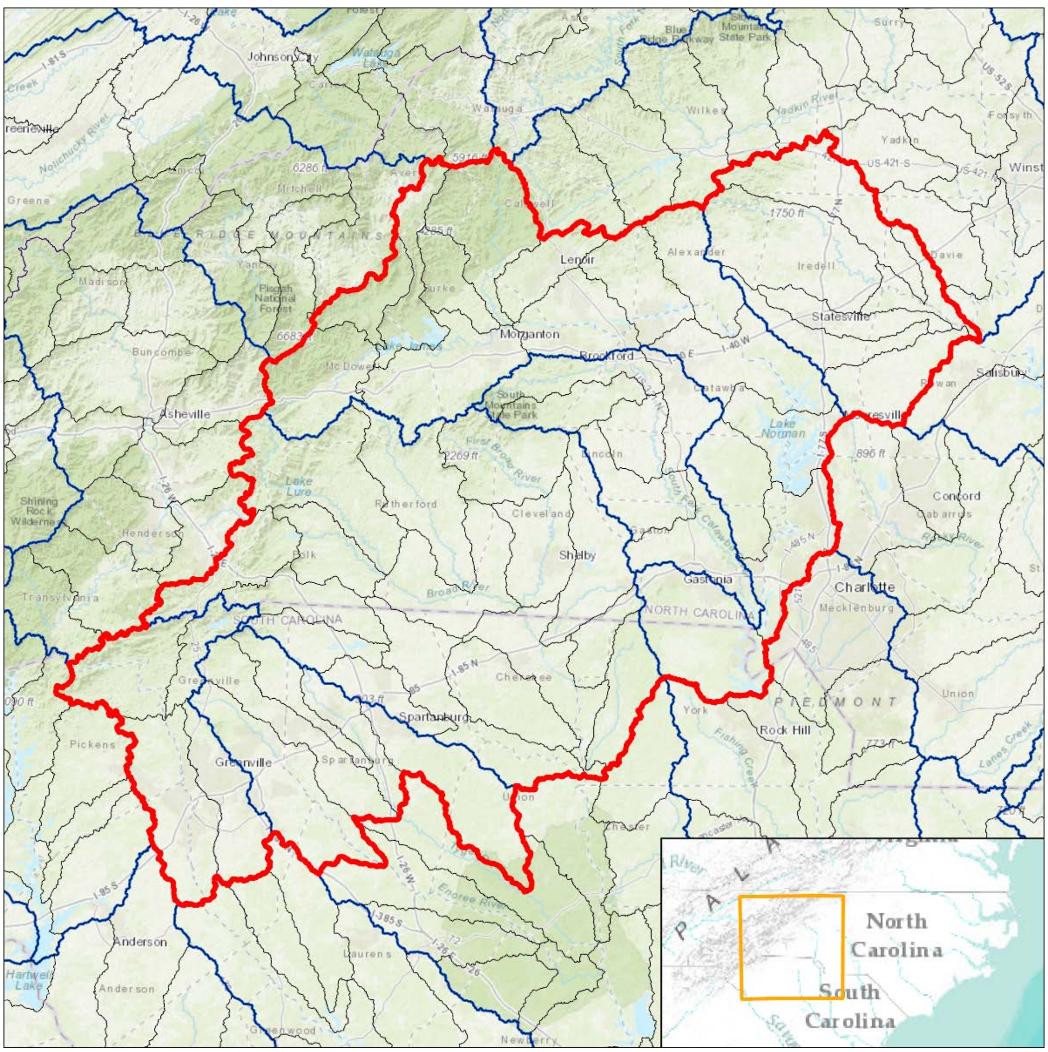
Appendix 3

Maxent Model Methodology

Study Extent, Coordinate System, and Cell Size

Fifty three 10-digit hydrologic units (HUC) comprise the analysis extent (Figure 1). In North Carolina it includes all 10-digit HUC that fall within the boundaries of 8-digit HUC with known occurrence of Hexastylis. In South Carolina we also included all 10-digit HUC that fell within the boundaries of 8-digit HUC with known occurrence of Hexastylis, but excluded the southern portions of the HUC-8 areas due to the boundaries being exceedingly large and far away from any known occurrences.

Figure 1. Analysis extent. 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



Coordinate System: USA Contiguous Albers Equal Area Conic USGS version

Cell Size: 30 x 30 meters derived from the USGS National GAP Landcover

Source Element Occurrence Data

Hexastylis naniflora element occurrence data was obtained from the North and South Carolina Natural Heritage Programs. These data were in polygon format and digitized at scale that accurately identified the boundaries of the individual population areas. 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 in the last 10 years (2007). 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.

Source Datasets Used:

USGS National GAP Landcover - The GAP National Terrestrial Ecosystems – Ver 3.0 is a 2011 update of the National Gap Analysis Program Land Cover Data – Version 2.2 for the conterminous U.S. The GAP National Terrestrial Ecosystems – Version 3.0 represents a highly thematically detailed land cover map of the U.S at a 30 x 30 meter pixel resolution. The map legend includes types described by NatureServe's Ecological Systems Classification (Comer et al. 2002) as well as land use classes described in the National Land Cover Dataset 2011 (Homer et al. 2015). These data cover the entire continental U.S. and are a continuous data layer. The land cover map identifies 49 different land cover types within the range of Hexastylis Naniflora.

LandFire - Landscape Fire and Resource Management Planning Tools, is a shared program between the wildland fire management programs of the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior, providing landscape scale geo-spatial products to support cross-boundary planning, management, and operations.

SSURGO Soils - The SSURGO database contains information about soil as collected by the National Cooperative Soil Survey over the course of a century. The information was gathered by walking over the land and observing the soil. Many soil samples were analyzed in laboratories. The maps outline areas called map units. The map units describe soils and other components that have unique properties, interpretations, and productivity. The information was collected at scales ranging from 1:12,000 to 1:63,360.

National Elevation Dataset - The NED is a seamless dataset with the best available raster elevation data of the conterminous United States, Alaska, Hawaii, and territorial islands. The NED is derived from diverse source data that are processed to a common coordinate system and unit of vertical measure. NED data are available nationally (except for Alaska) at resolutions of 1 arc-second (about 30 meters) and 1/3 arc-second (about 10 meters), and in limited areas at 1/9 arc-second (about 3 meters). The 1/3 arc-second database was used for HENA modelling purposes.

PRISM Climate Data - The PRISM Climate Group gathers climate observations from a wide range of monitoring networks, applies sophisticated quality control measures, and develops spatial climate datasets to reveal short- and long-term climate patterns. The resulting datasets incorporate a variety of modeling techniques and are available at multiple spatial/temporal resolutions, covering the period from 1895 to the present.

Model Variables Created:

Landcover – Landcover represented by the default landcover classification (Table 1).

Landcover Hexastylis Grouping – Landcover represented by a grouping of landcover types. For the purposes of discussing Hexastylis naniflora habitat, many of the default landcover classifications are similar and could be grouped together. The definition of each landcover classification was reviewed and categorized using a much broader habitat definition (Table 1).

Table 1. Landcover classification

Default Landcover Classification	Hexastylis Grouping
Southern Piedmont Glade and Barrens	Barren
Southern Ridge and Valley / Cumberland Dry Calcareous Forest	Barren
Undifferentiated Barren Land	Barren
Cultivated Cropland	Disturbed
Deciduous Plantations	Disturbed
Developed, High Intensity	Disturbed
Developed, Low Intensity	Disturbed
Developed, Medium Intensity	Disturbed
Developed, Open Space	Disturbed
Disturbed/Successional - Grass/Forb Regeneration	Disturbed
Disturbed/Successional - Shrub Regeneration	Disturbed
Evergreen Plantation or Managed Pine	Disturbed
Harvested Forest - Grass/Forb Regeneration	Disturbed
Harvested Forest-Shrub Regeneration	Disturbed
Introduced Upland Vegetation - Annual Grassland	Disturbed
Introduced Upland Vegetation - Shrub	Disturbed
Introduced Upland Vegetation - Treed	Disturbed
Pasture/Hay	Disturbed
Quarries, Mines, Gravel Pits and Oil Wells	Disturbed
Ruderal forest	Disturbed
Southern Appalachian Low Mountain Pine Forest	Evergreen
Southern Appalachian Montane Pine Forest and Woodland	Evergreen
Southern and Central Appalachian Cove Forest	Hardwood
Southern and Central Appalachian Oak Forest	Hardwood
Southern and Central Appalachian Oak Forest - Xeric	Hardwood
Southern Piedmont Mesic Forest	Hardwood

Central and Southern Appalachian Montane Oak Forest	High Elevation
Central and Southern Appalachian Northern Hardwood Forest	High Elevation
Central and Southern Appalachian Spruce-Fir Forest	High Elevation
Southern Appalachian Grass and Shrub Bald	High Elevation
Southern Appalachian Grass and Shrub Bald - Shrub Modifier	High Elevation
Appalachian Hemlock-Hardwood Forest	Mixed
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	Mixed
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	Mixed
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	Mixed
Southern Ridge and Valley Dry Calcareous Forest	Mixed
Southern Ridge and Valley Dry Calcareous Forest - Pine modifier	Mixed
Open Water (Fresh)	Open Water/Wetland
Southern and Central Appalachian Bog and Fen	Open Water/Wetland
Southern Piedmont/Ridge and Valley Upland Depression Swamp	Open Water/Wetland
Southern Appalachian Granitic Dome	Outcrop
Southern Appalachian Montane Cliff	Outcrop
Southern Appalachian Rocky Summit	Outcrop
Southern Piedmont Cliff	Outcrop
Southern Piedmont Granite Flatrock	Outcrop
South-Central Interior Large Floodplain - Forest Modifier	Riparian
South-Central Interior Small Stream and Riparian	Riparian
Southern Piedmont Large Floodplain Forest - Forest Modifier	Riparian
Southern Piedmont Small Floodplain and Riparian Forest	Riparian

Landcover Diversity – Identifies the number of landcover classes (default classification) within a 10-cell radius (300 meters) of an individual pixel.

Landcover Majority – Identifies the dominant landcover class (default classification) within a 10-cell radius (300 meters) of an individual pixel.

Landfire Canopy Height – Represents the vertically projected percent cover of the live vegetation canopy.

Landfire Canopy Cover – Represents the average height of the dominant vegetation across the landscape.

SSURGO mukey – SSURGO soils dataset represented by the Map Unit Key (mukey)

SSURGO Drainage Class – SSURGO soils dataset represented by wettest drainage class. Drainage class refers to the frequency and duration of wet periods in conditions similar to those under which the soil formed.

SSURGO Hydrologic Group – SSURGO soils dataset represented by hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

Elevation – National elevation dataset elevation values. This 10-meter dataset was reclassified to 30-meters.

Aspect 9-class – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, Northeast, East, Southeast, South, Southwest, West, and Northwest.

Aspect 5-class – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, East, South, and West.

Slope – The national elevation dataset represented by degree of slope.

Geomorphons – A pattern recognition analysis that converts a digital elevation dataset into 10 common landform elements: flat, peak, ridge, shoulder, spur, slope, pit, valley, footslope, and hollow. The national elevation dataset was used as the source elevation for the analysis.

Solar Radiation – An analysis of the amount of solar radiation (radiant energy) reaching the earth's surface using the national elevation dataset as the elevation model. The output solar model is reported in watt hours per square meter (WH/m^2)

Average Annual Precipitation – Climate dataset of average annual precipitation according to a model using point precipitation and elevation data for the 30-year period of 1971-2000.

Maximum Average Annual Temperature – Climate dataset of average annual maximum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

Minimum Average Annual Temperature – Climate dataset of average annual minimum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

Maxent Model Development

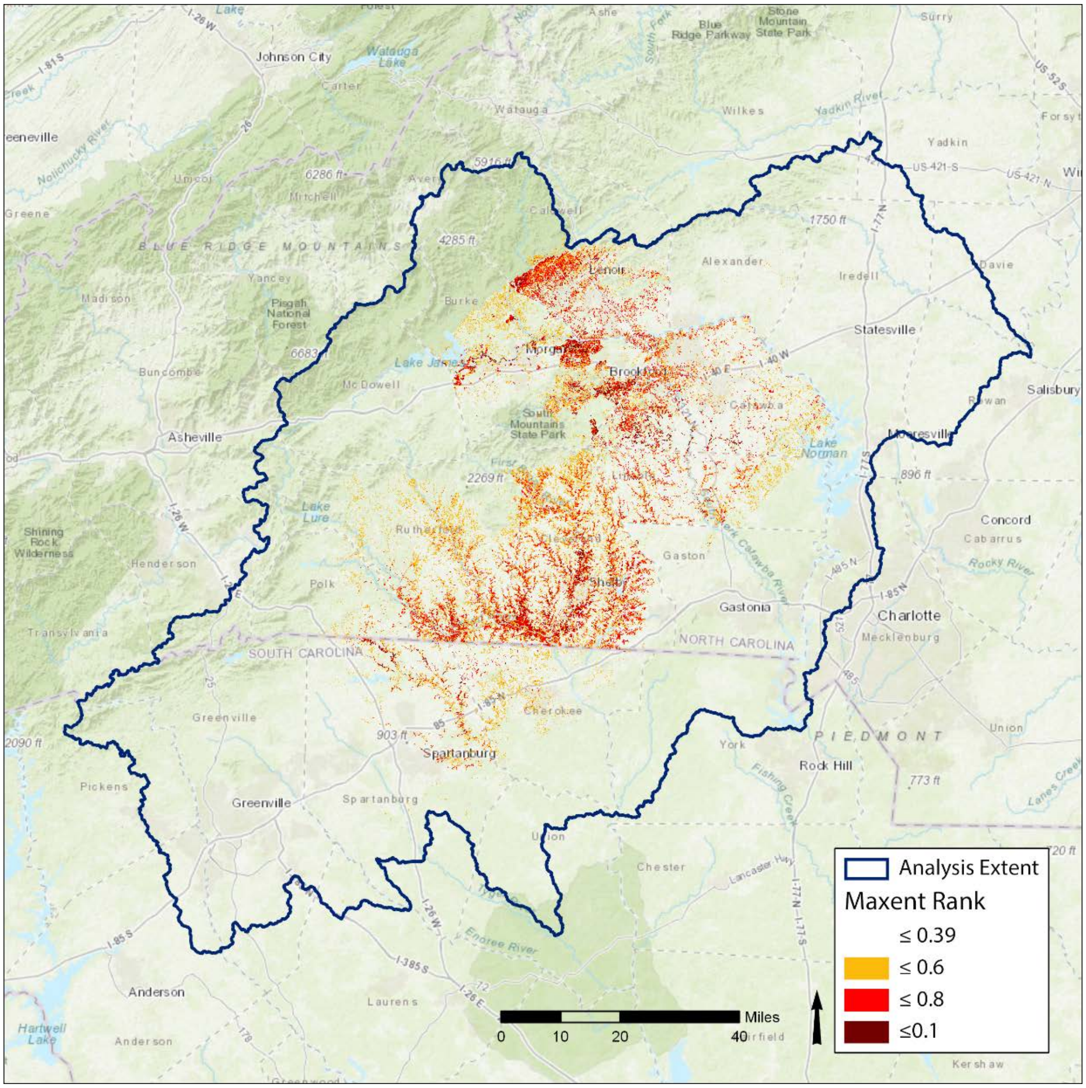
Maxent software for species habitat modeling (version 3.4.1) was used (Philips et al., 2018).

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, aspect 5-class, slope, solar radiation, and maximum annual temperature.

For the final model a 10-run replicate Maxent model was created using crossvalidation. 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. Cloglog output format was used. Cloglog output gives an estimate between 0 and 1 of probability of presence assuming an appropriate sampling design.

Figure 2. Maxent model output map.



Results

Figure 2 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 predictions to focus on the typical habitat conditions for this species. The total area ranked greater than 0.39 in the Maxent model was just 6.0% of the total analysis area (Table 1).

Table 1. Area estimates of the Maxent model

Maxent Score	Acres	Square Miles	Percent of Total
0.406 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%

The average area-under-curve (AUC) score for the replicate Maxent model is 0.86. The AUC is calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1 and may be interpreted as a single test statistic that assesses model performance, indicating the ability of the model to correctly classify the occurrence data used. AUC values close to 0.50 indicate a model fit no better than random, values less than 0.5 indicate a model fit worse than random, a value of 1.0 indicate a perfect fit (Baldwin 2009). A value of 0.86 is a good fitting model.

The Maxent output supplies estimates of the relative contributions of the environmental variables to the Maxent model (Table 2.)

Table 2. Percent contribution of the environmental variables

Environmental Variable	Percent Contribution
SSURGO mukey	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 mukey is the top contributing variable. 135 different individual soil types are present within the polygon boundaries of the Hexastylis element occurrences. Many of these individual soil types are part of soil complexes and are separated by things such as percent slope, erosion, how stony/rocky, and amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25 to 60 percent slopes, very stony (14.1% of total). However, collectively the Meadowfield soils only comprised 14.3% of all soils). The individual Pacolet soil types were very common and collectively comprise 32.2% of all soil types present. Woolwine, Rion, and Fairview soils were also collectively common, comprising 10.4%, 9.7%, and 8.8% of all soils present respectively.

The minimum annual average temperature range in the analysis extent is 39 – 51 degrees Fahrenheit. The majority of the Hexastylis 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 element occurrences (82%) are found in the 47 – 49 inches per year range.

Piedmont forested landcover habitats dominate the land area of the element occurrences. 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. Unfortunately, non-native habitats are also present. 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 landcover classes, but each at small percentages.

The landcover majority classification scheme reduces the total number of landcover classes present in the analysis extent from 23 to 11. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landcover 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 landcover area representation in the landcover majority layer suggests that many Hexastylis population areas are situated in areas impacted by disturbed landcover. This is likely due to urban encroachment and increasing fragmentation of habitats.

The landcover Hexastylis grouping reveals the amount of disturbance present in Hexastylis population areas. Landcover classes grouped as disturbed comprises 27% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, pasture/hay 12%, and hardwood forest 2%,

Geomorphons revealed that the majority of Hexastylis element occurrence areas are situated in concave landforms. Geomorphon categories hollow (13%), valley (46%), and depression (10%) collectively comprise 69% of all Hexastylis 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, 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 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.

Citations

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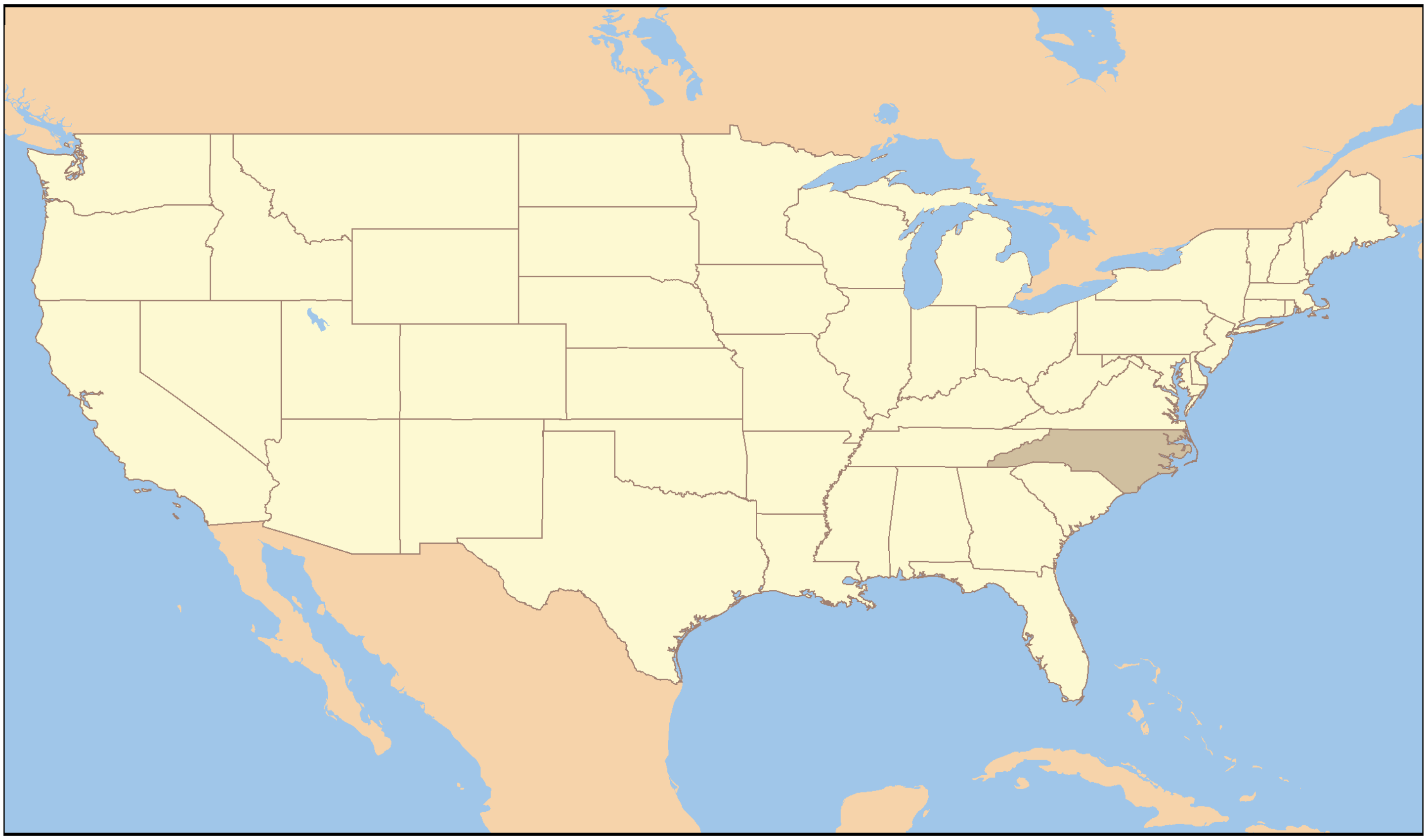
Steven J. Phillips, Miroslav Dudík, Robert E. Schapire. [Internet] Maxent software for modeling species niches and distributions (Version 3.4.1). Available from url: http://biodiversityinformatics.amnh.org/open_source/maxent/. Accessed on 2018-2-20.

Appendix 4a

U.S. Geological Survey - National Climate Change Viewer

Summary of North Carolina



December 1, 2016

1 Maximum 2-m Air Temperature

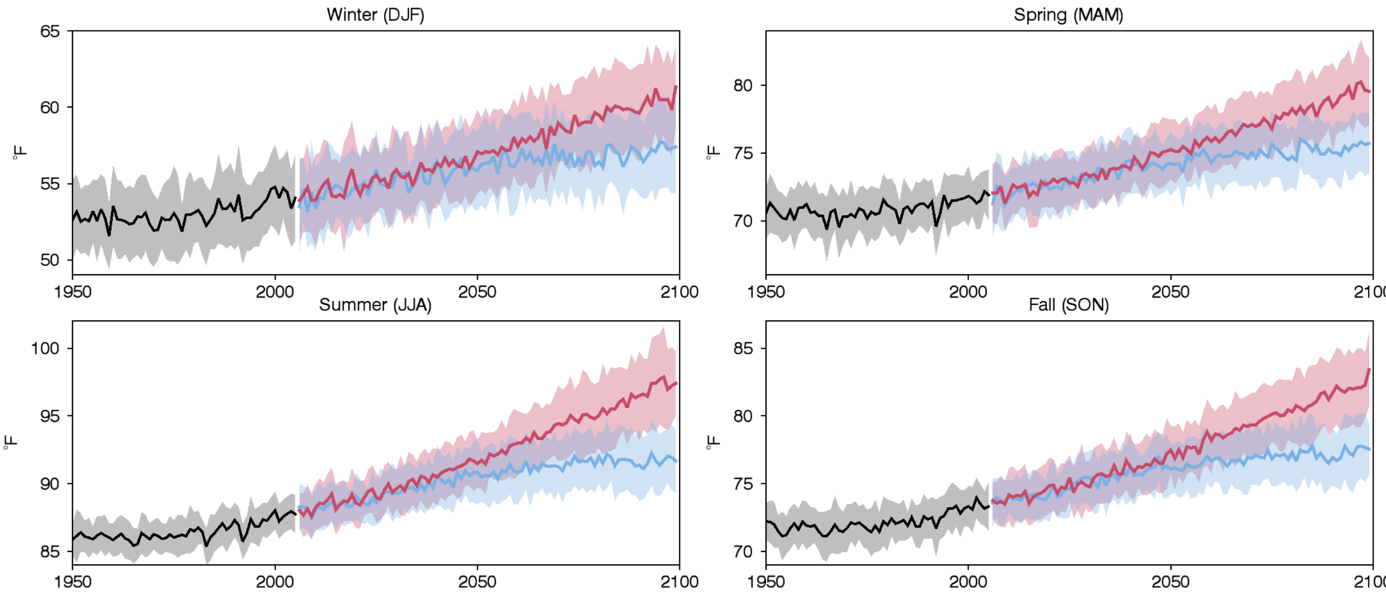


Figure 1: Seasonal average time series of maximum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

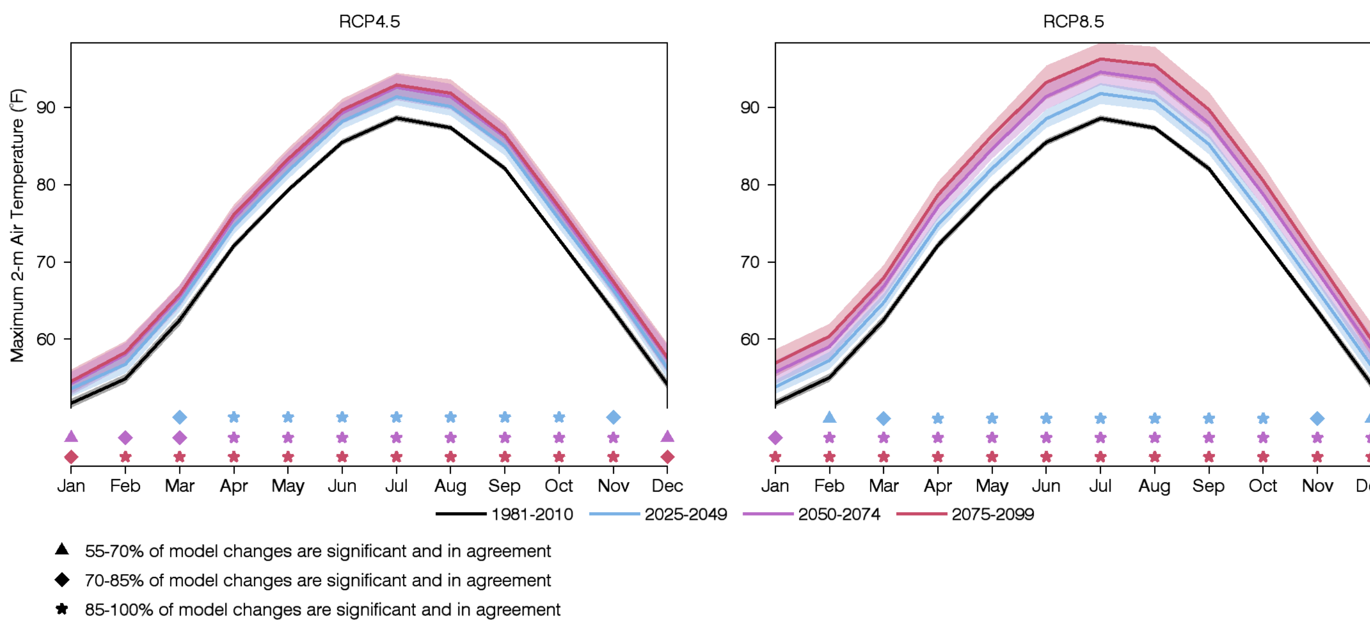


Figure 2: Monthly averages of maximum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

2 Minimum 2-m Air Temperature

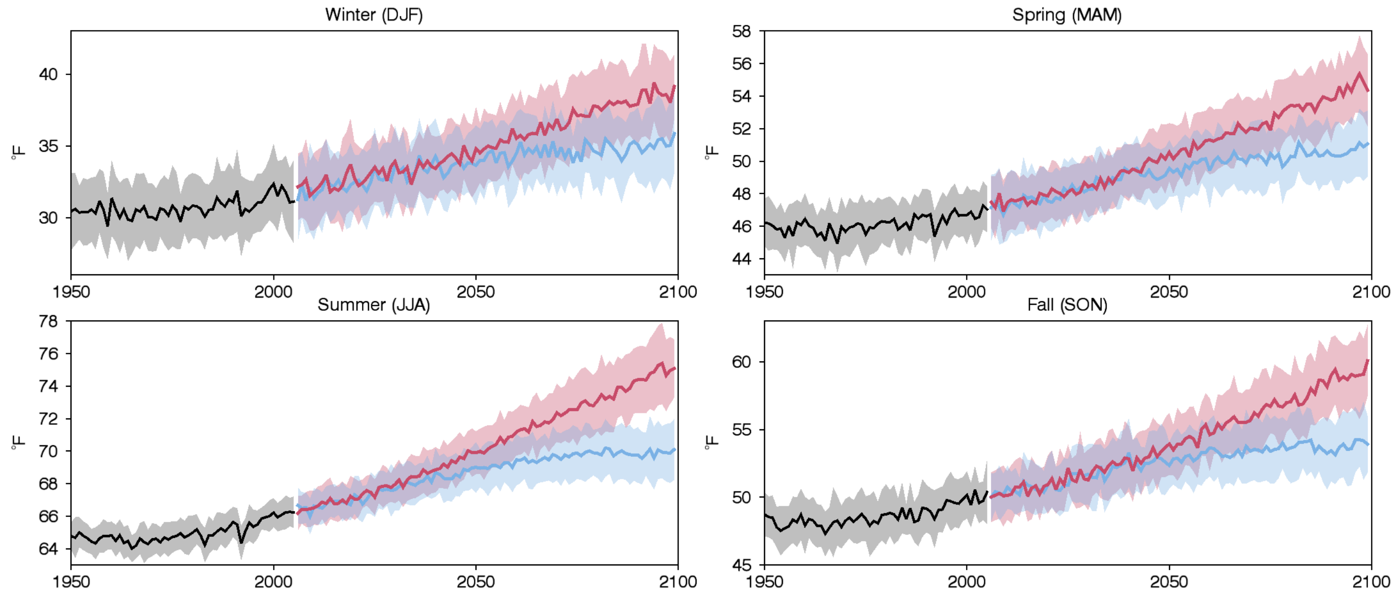


Figure 3: Seasonal average time series of minimum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

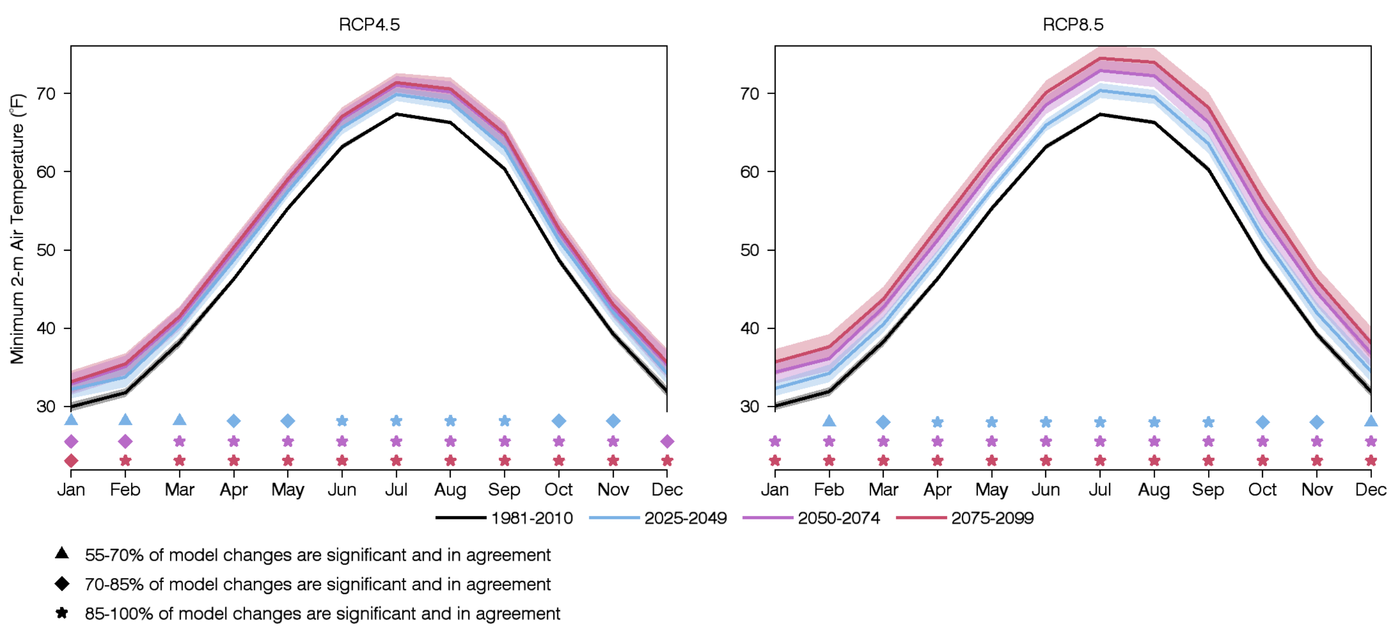


Figure 4: Monthly averages of minimum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

3 Precipitation

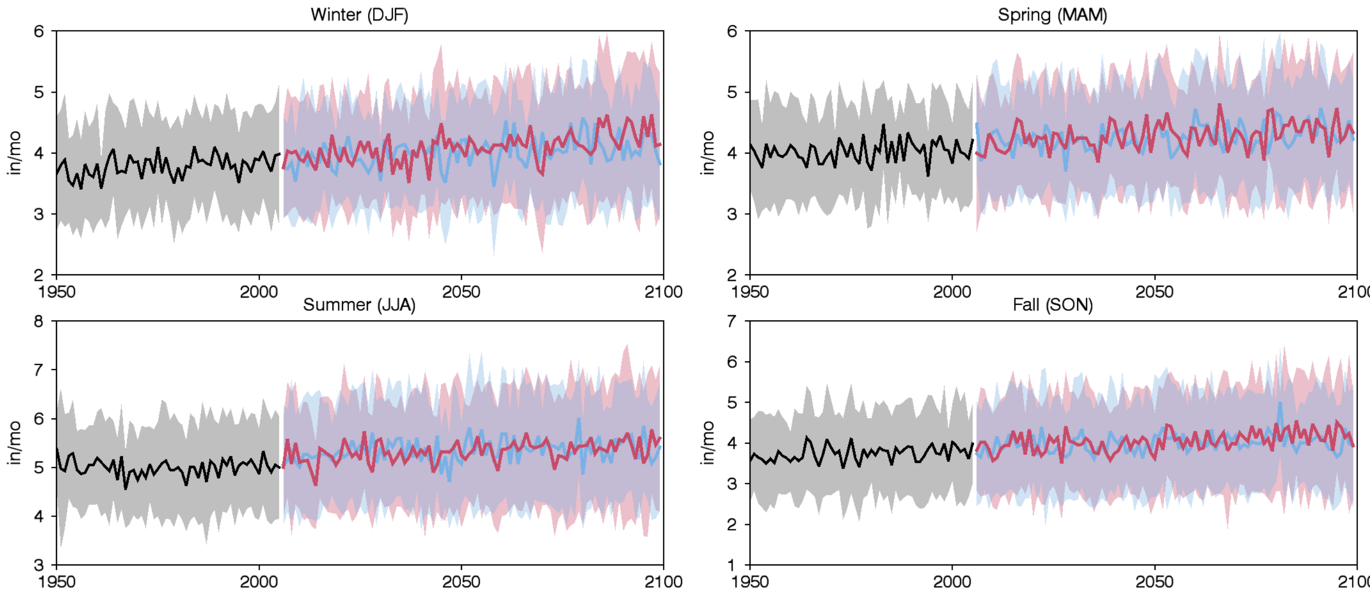


Figure 5: Seasonal average time series of precipitation for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

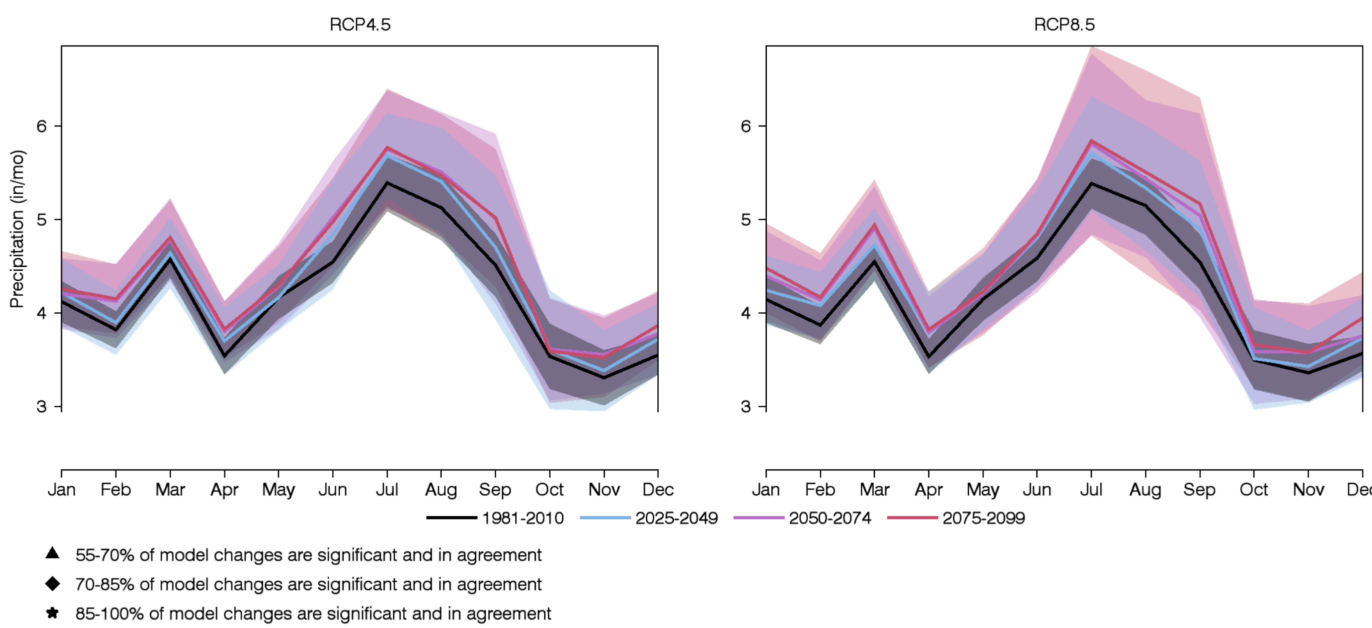


Figure 6: Monthly averages of precipitation for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

4 Snow Water Equivalent

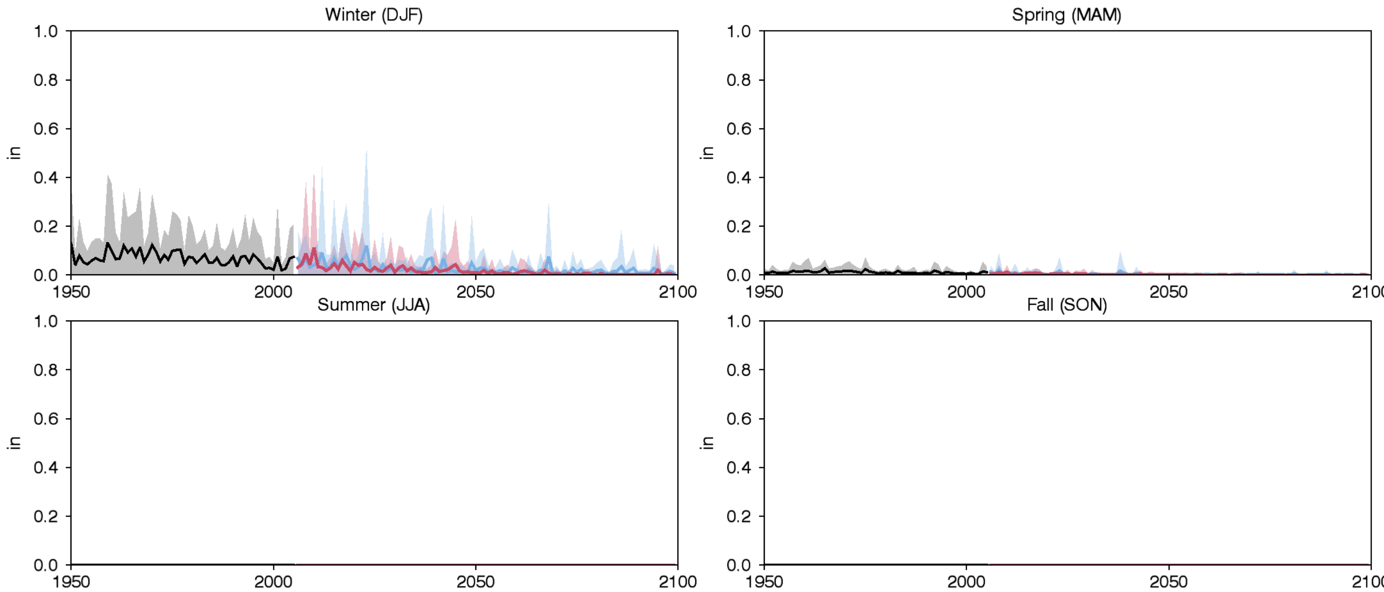


Figure 7: Seasonal average time series of snow water equivalent for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

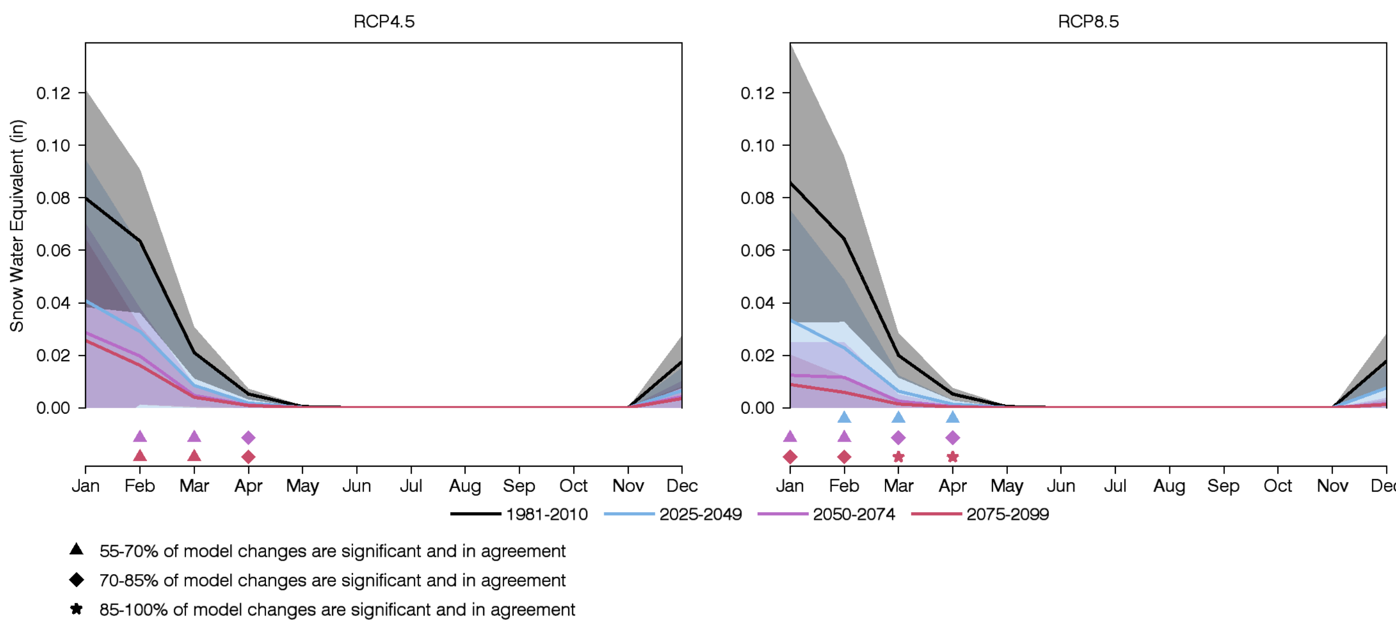


Figure 8: Monthly averages of snow water equivalent for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

5 Runoff

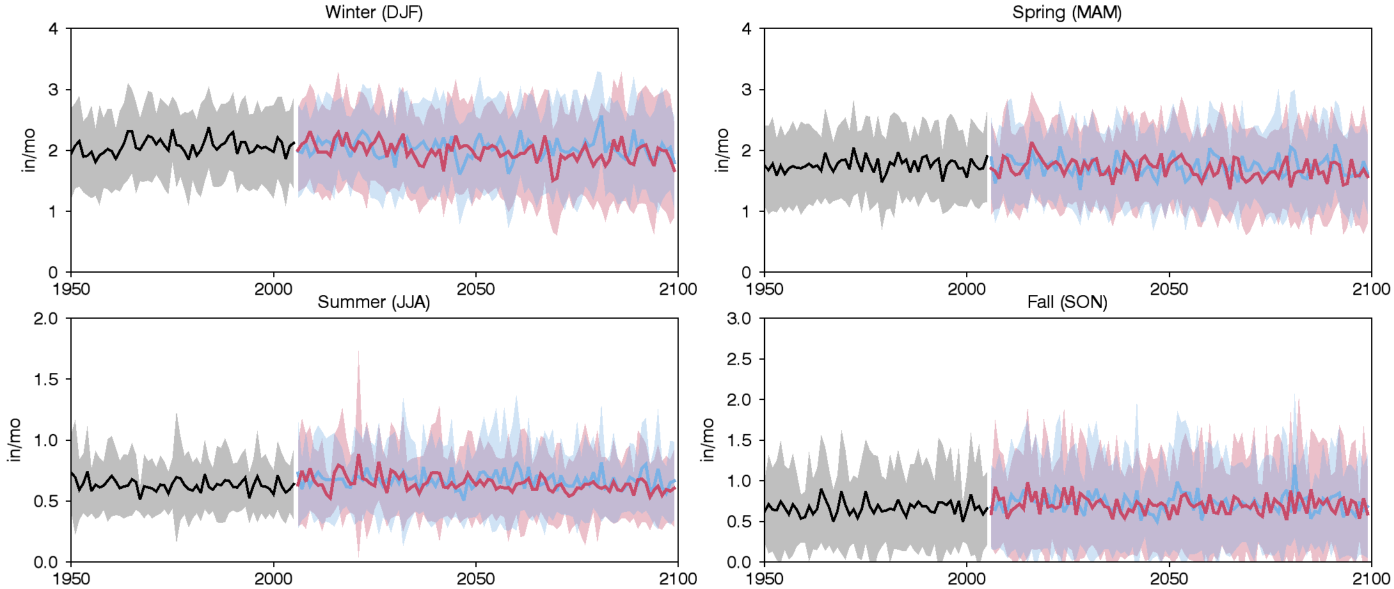


Figure 9: Seasonal average time series of runoff for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

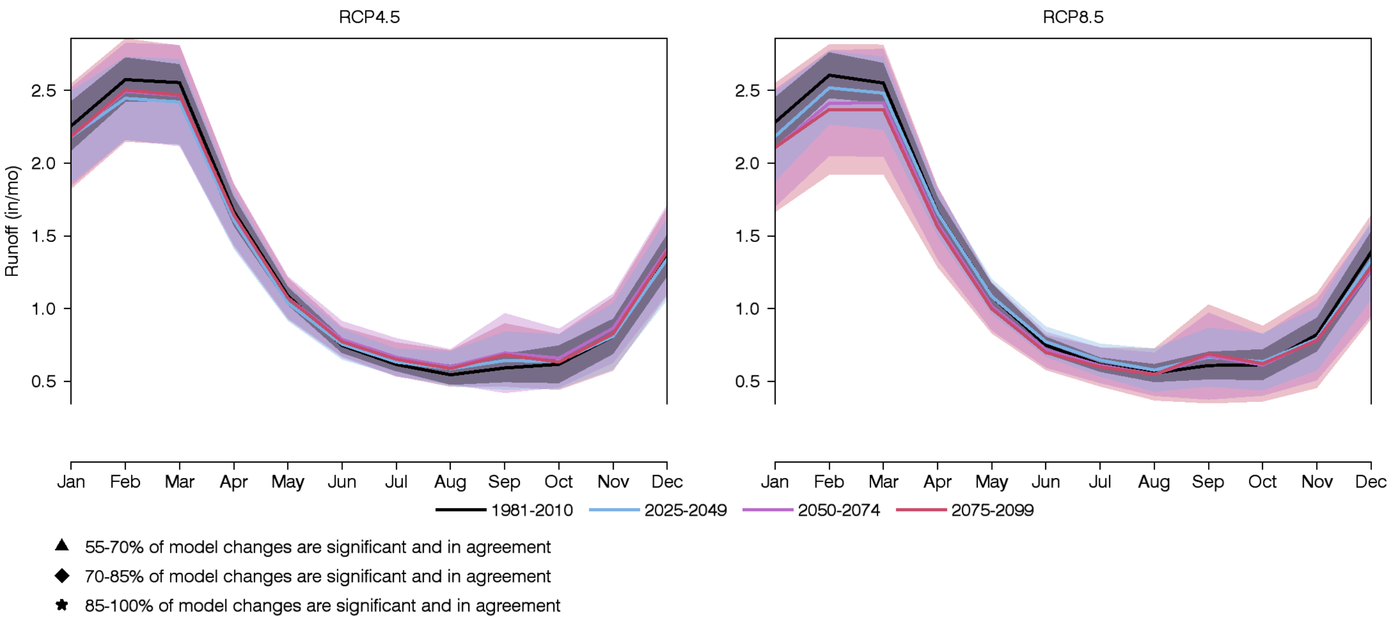


Figure 10: Monthly averages of runoff for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

6 Soil Water Storage

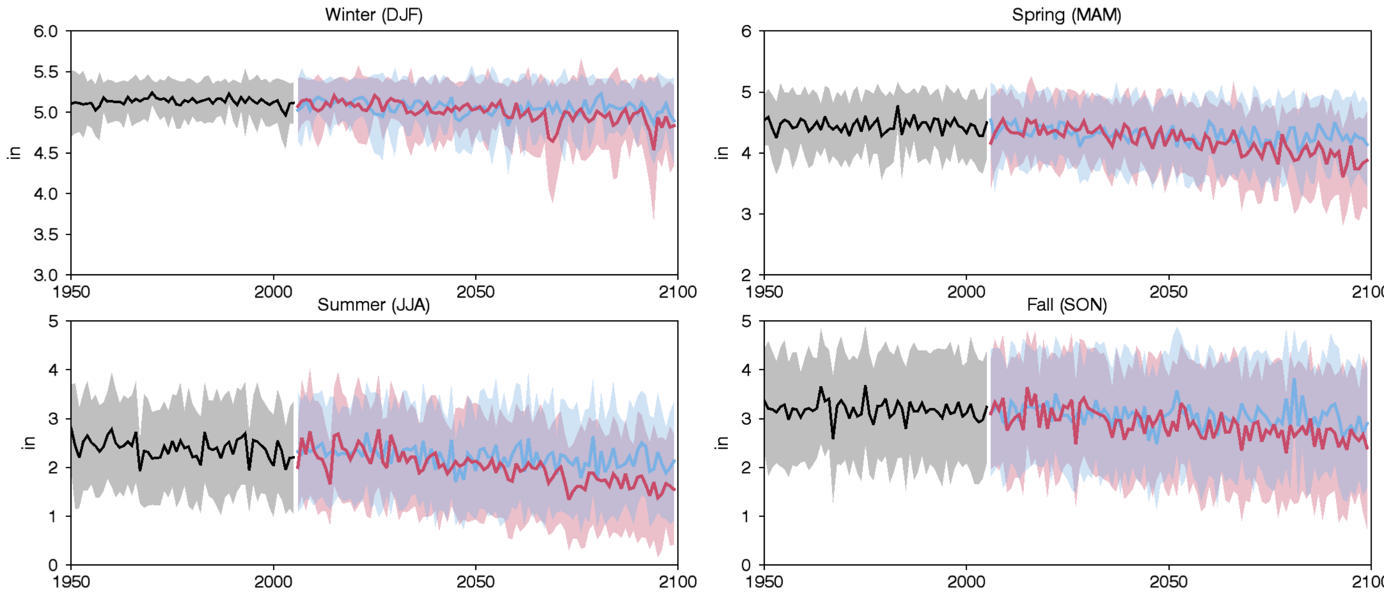


Figure 11: Seasonal average time series of soil water storage for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

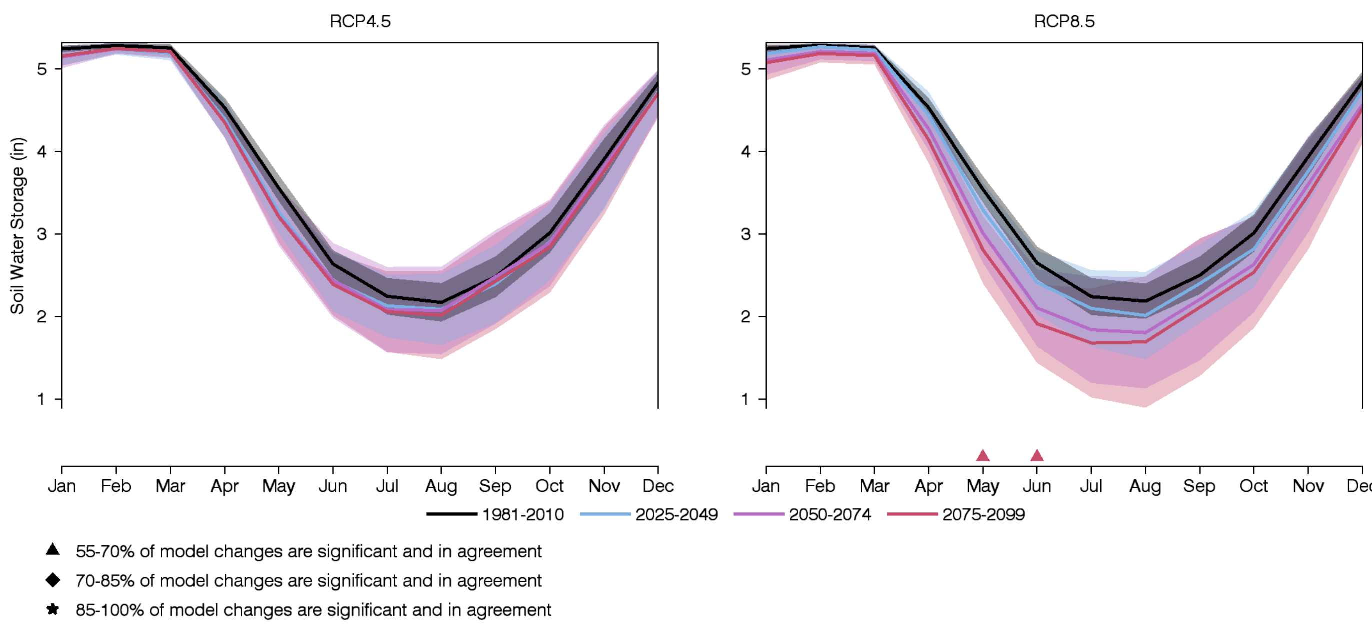


Figure 12: Monthly averages of soil water storage for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

7 Evaporative Deficit

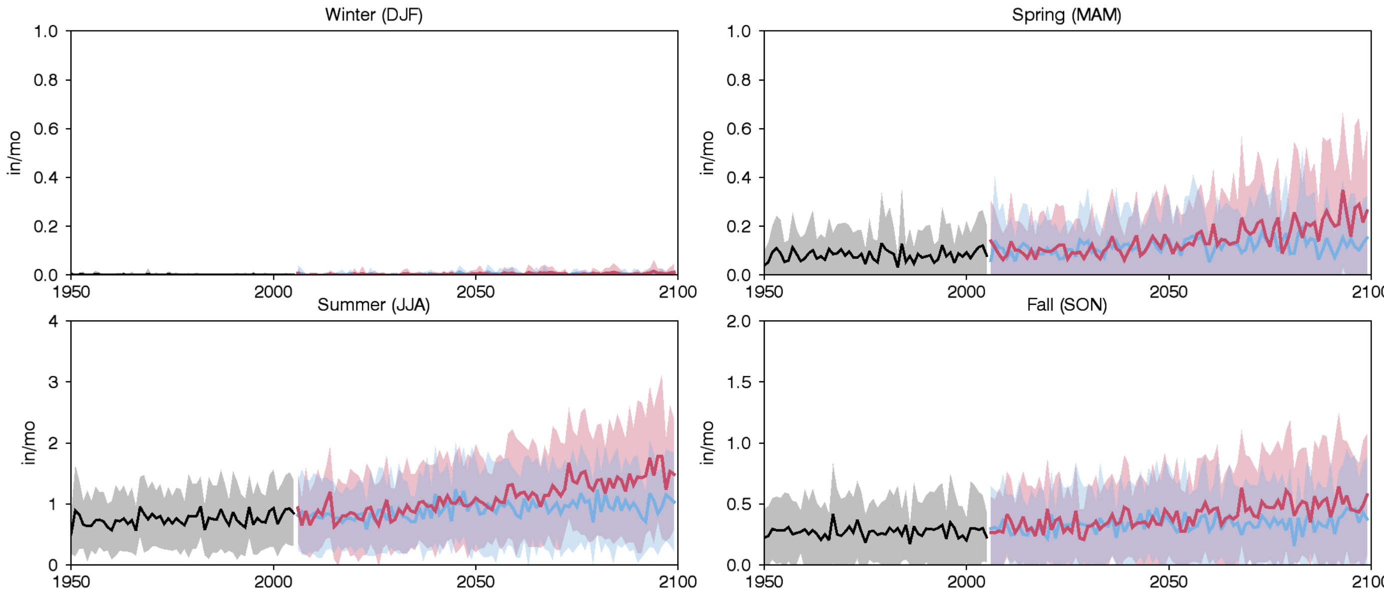


Figure 13: Seasonal average time series of evaporative deficit for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

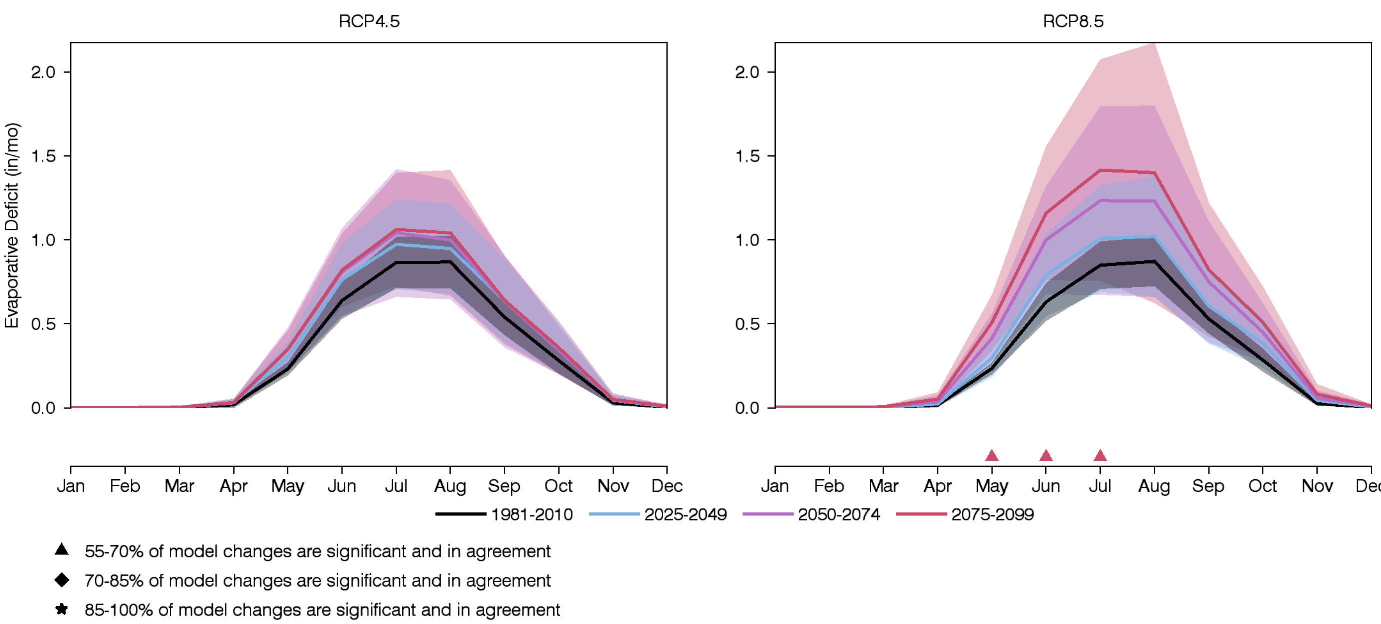


Figure 14: Monthly averages of evaporative deficit for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

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9 Models

ACCESS1-0	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4
CESM1-BGC	CMCC-CM	CNRM-CM5	CSIRO-Mk3-6-0	FGOALS-g2	FIO-ESM
GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M	GISS-E2-R	HadGEM2-AO	HadGEM2-CC
HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5
MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MPI-ESM-MR	MRI-CGCM3	NorESM1-M

10 Citation Information

Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer. US Geological Survey `http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp` doi:10.5066/F7W9575T.

Hostetler, S.W. and Alder, J.R., 2016. Implementation and evaluation of a monthly water balance model over the U.S. on an 800 m grid. Water Resources Research, 52, doi:10.1002/2016WR018665.

Thrasher, B., J. Xiong, W. Wang, F. Melton, A. Michaelis, and R. Nemani, 2013. New downscaled climate projections suitable for resource management in the U.S. Eos, Transactions American Geophysical Union 94, 321-323, doi:10.1002/2013EO370002.

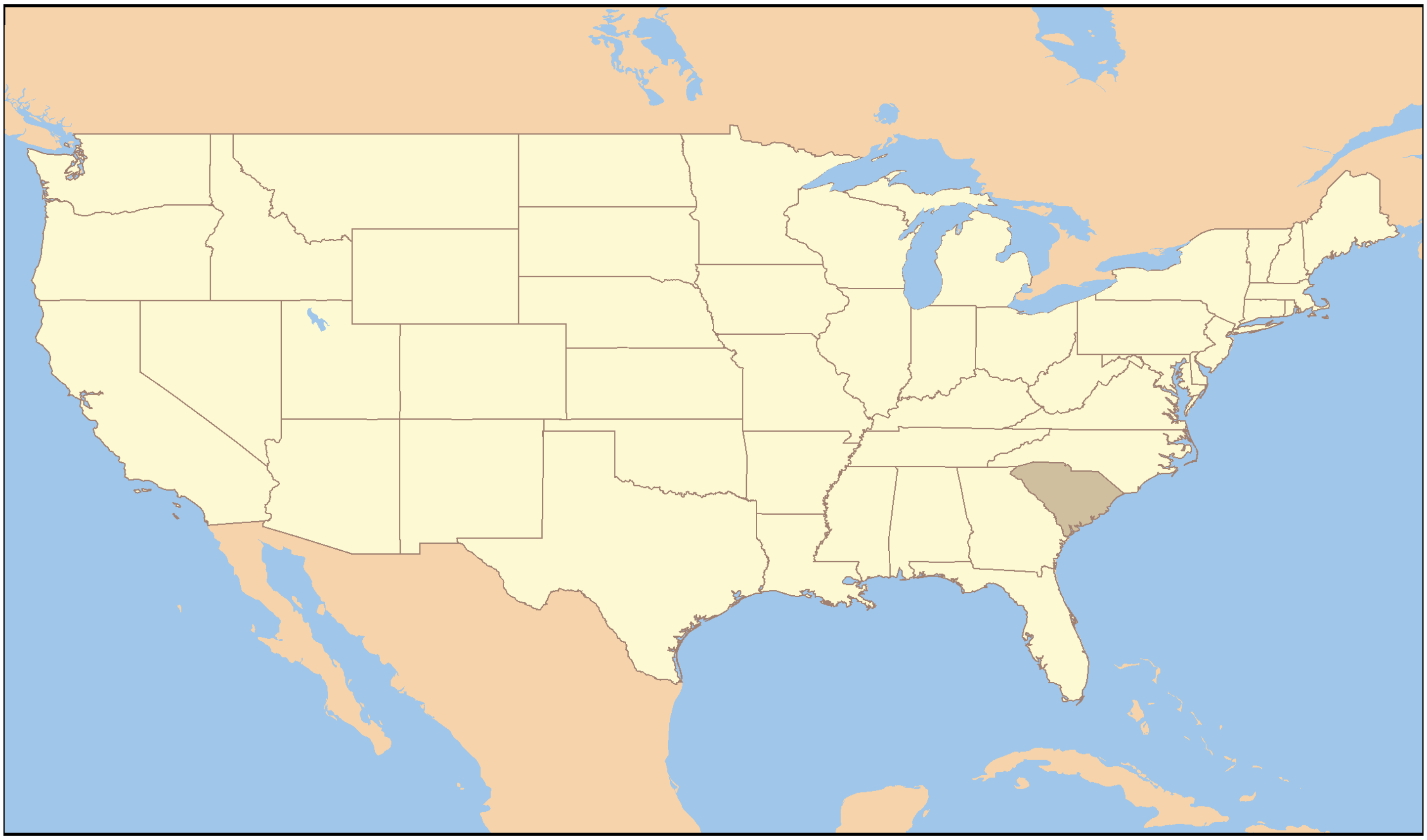
11 Disclaimer

These freely available, derived data sets were produced by J. Alder and S. Hostetler, US Geological Survey (USGS). The original climate data are from the NEX-DCP30 dataset, which was prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and is distributed by the NASA Center for Climate Simulation. No warranty expressed or implied is made by the USGS regarding the display or utility of the derived data on any other system, or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. The USGS shall not be held liable for improper or incorrect use of the data described and/or contained herein.

Appendix 4b

U.S. Geological Survey - National Climate Change Viewer

Summary of South Carolina



December 1, 2016

1 Maximum 2-m Air Temperature

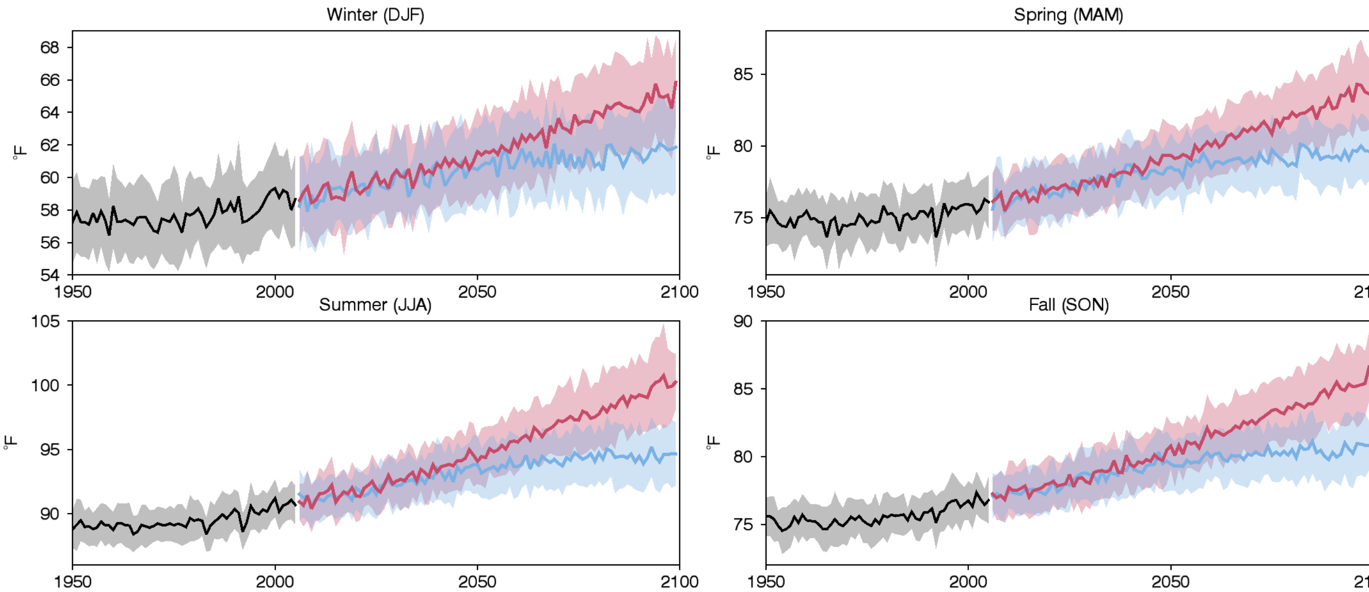


Figure 1: Seasonal average time series of maximum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

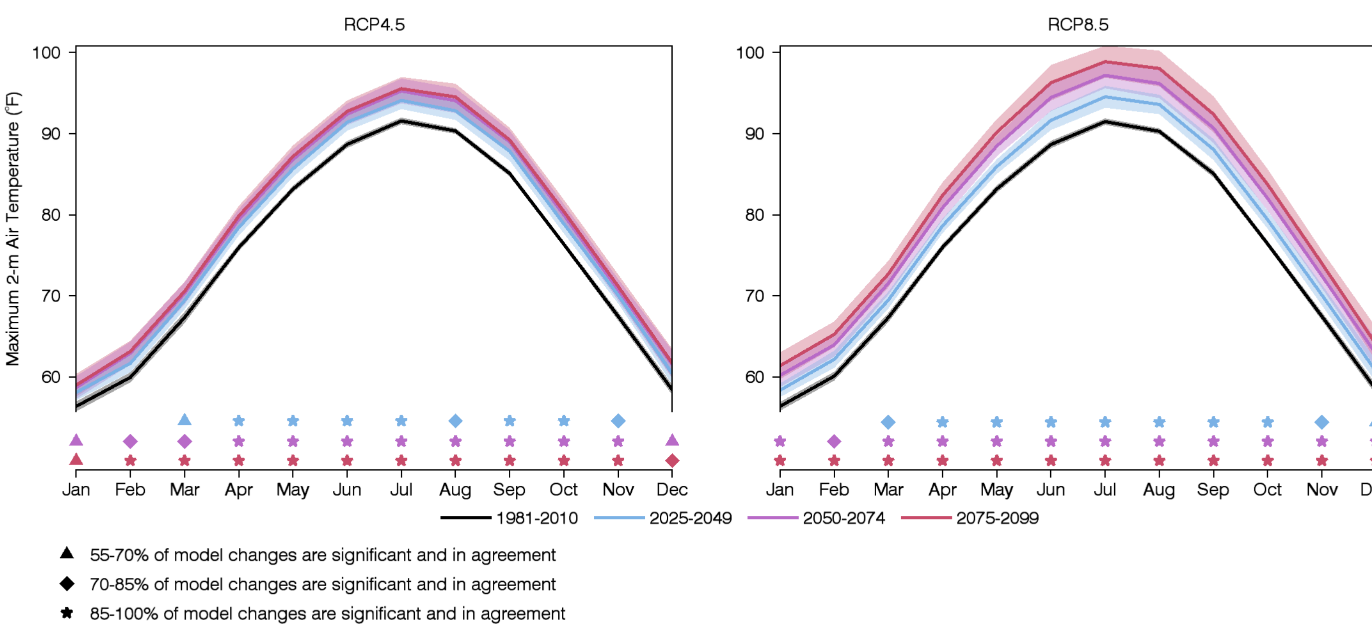


Figure 2: Monthly averages of maximum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

2 Minimum 2-m Air Temperature

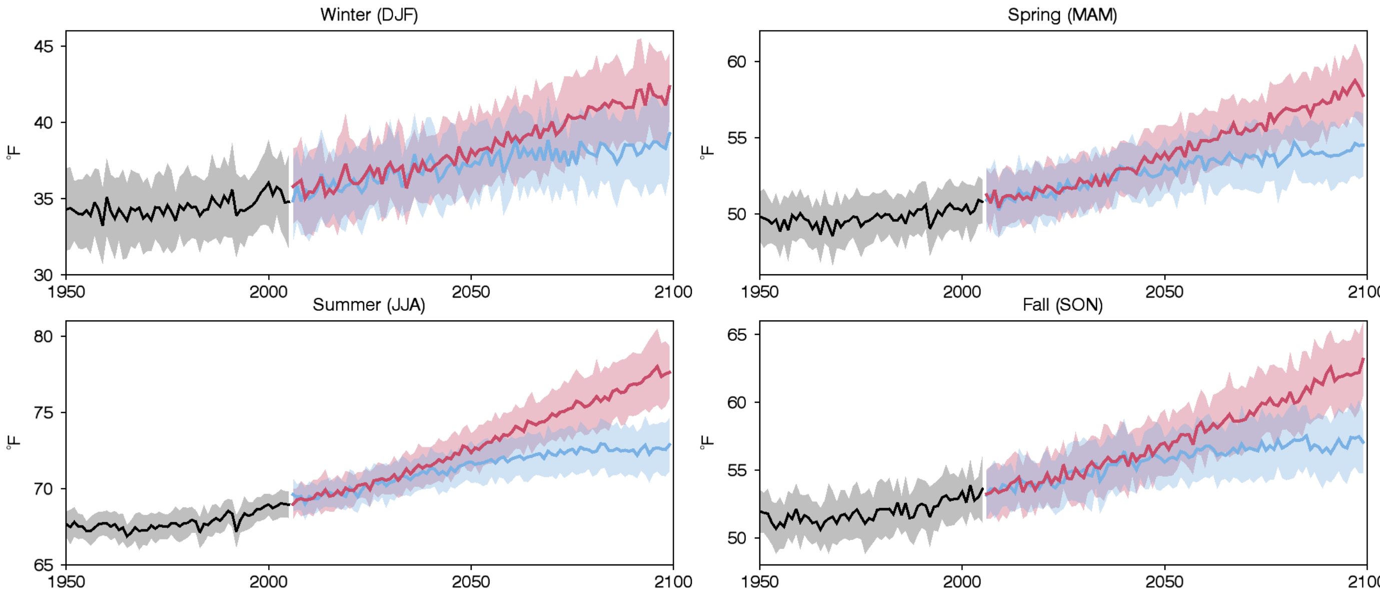


Figure 3: Seasonal average time series of minimum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

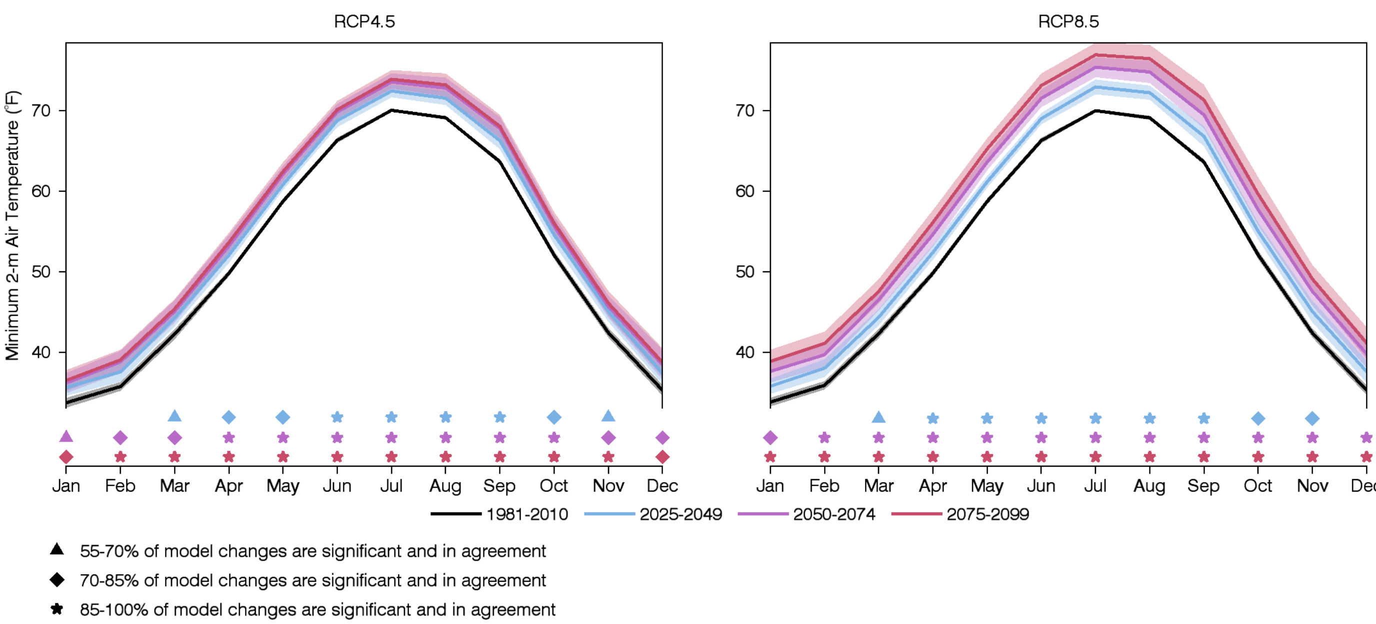


Figure 4: Monthly averages of minimum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

3 Precipitation

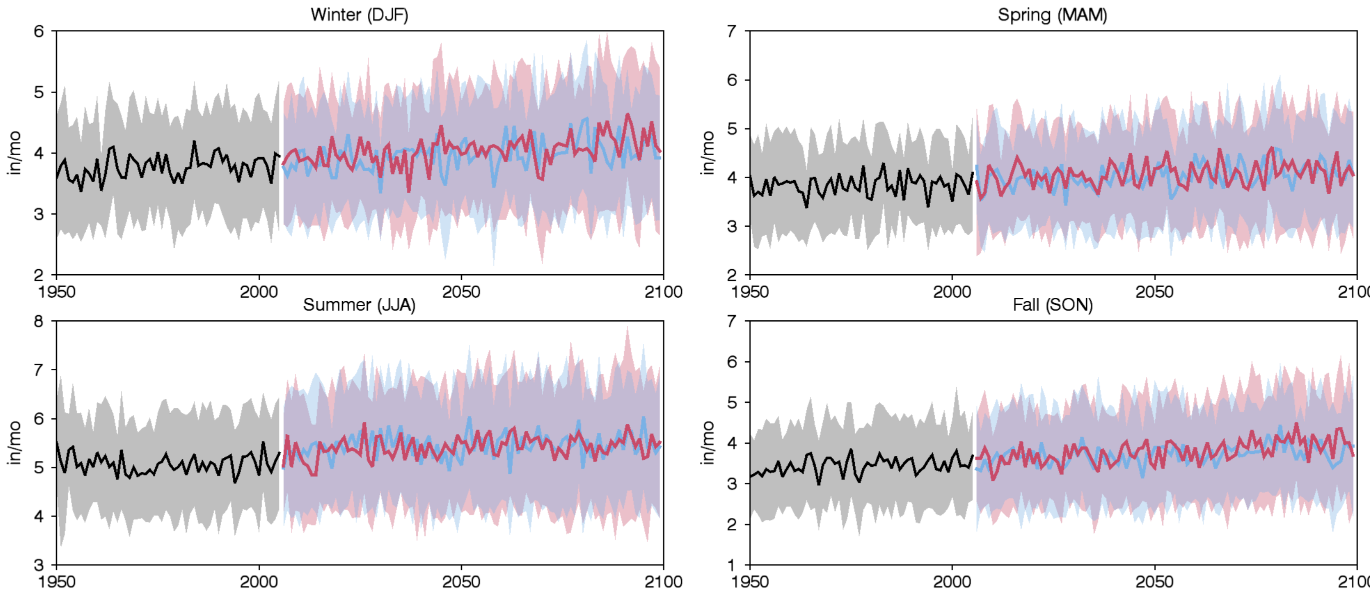


Figure 5: Seasonal average time series of precipitation for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

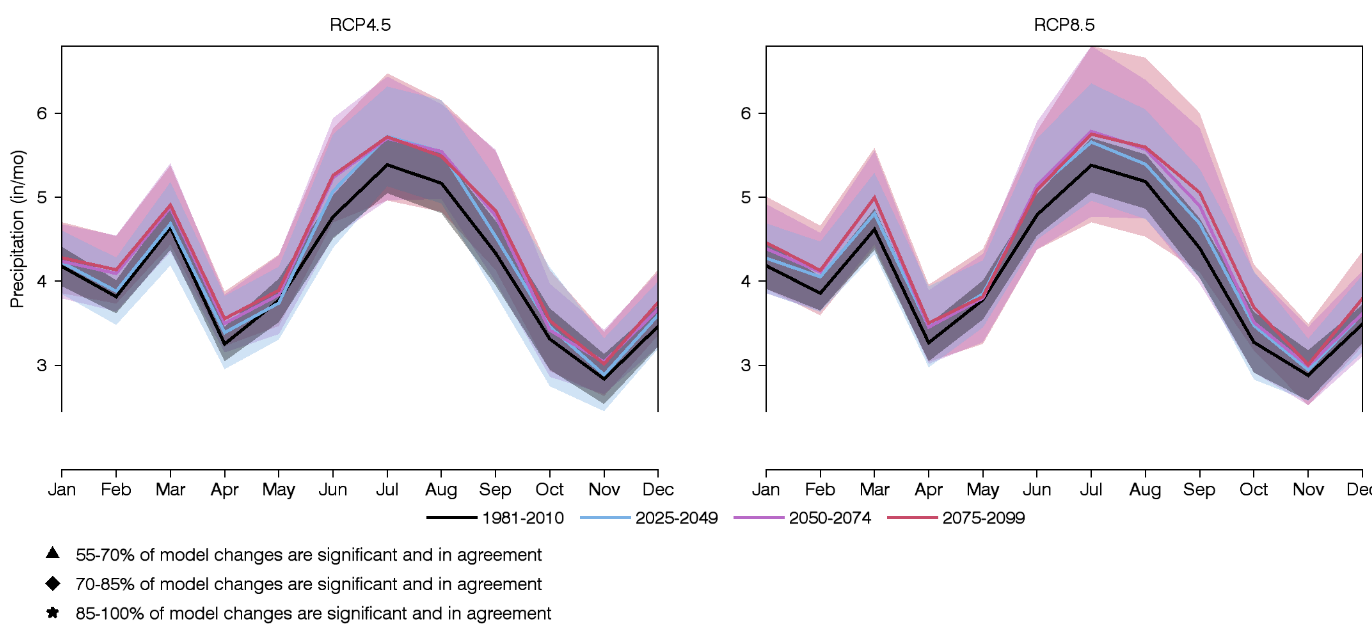


Figure 6: Monthly averages of precipitation for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

4 Snow Water Equivalent

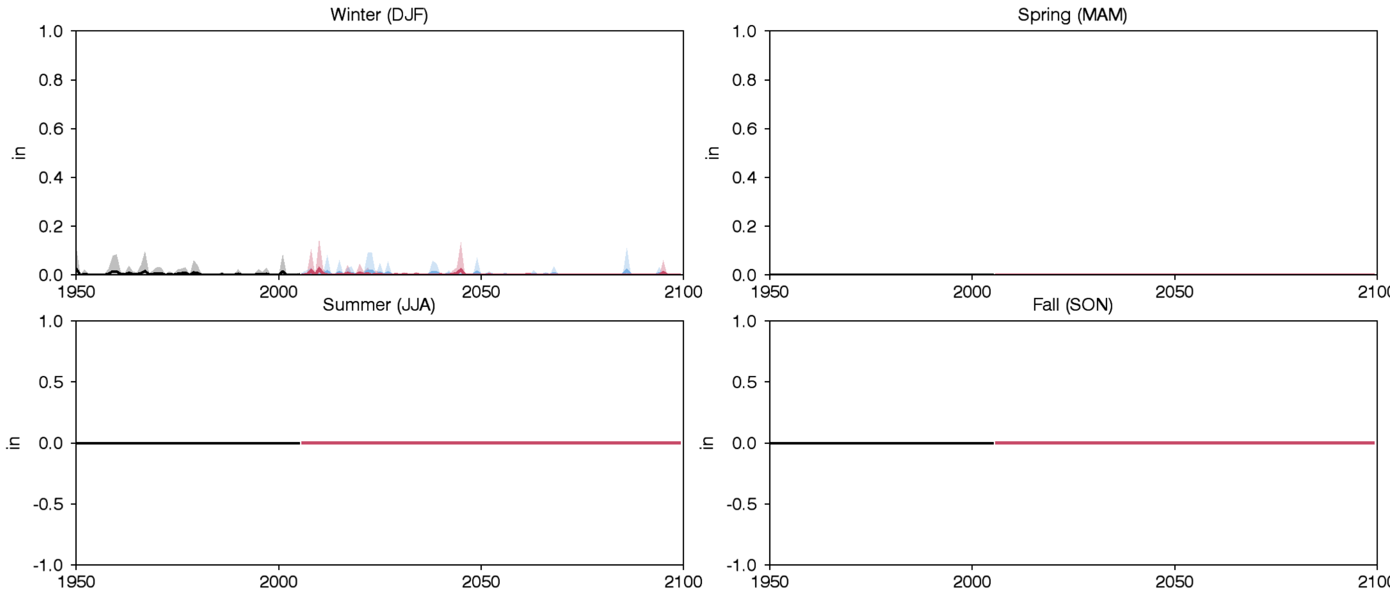


Figure 7: Seasonal average time series of snow water equivalent for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

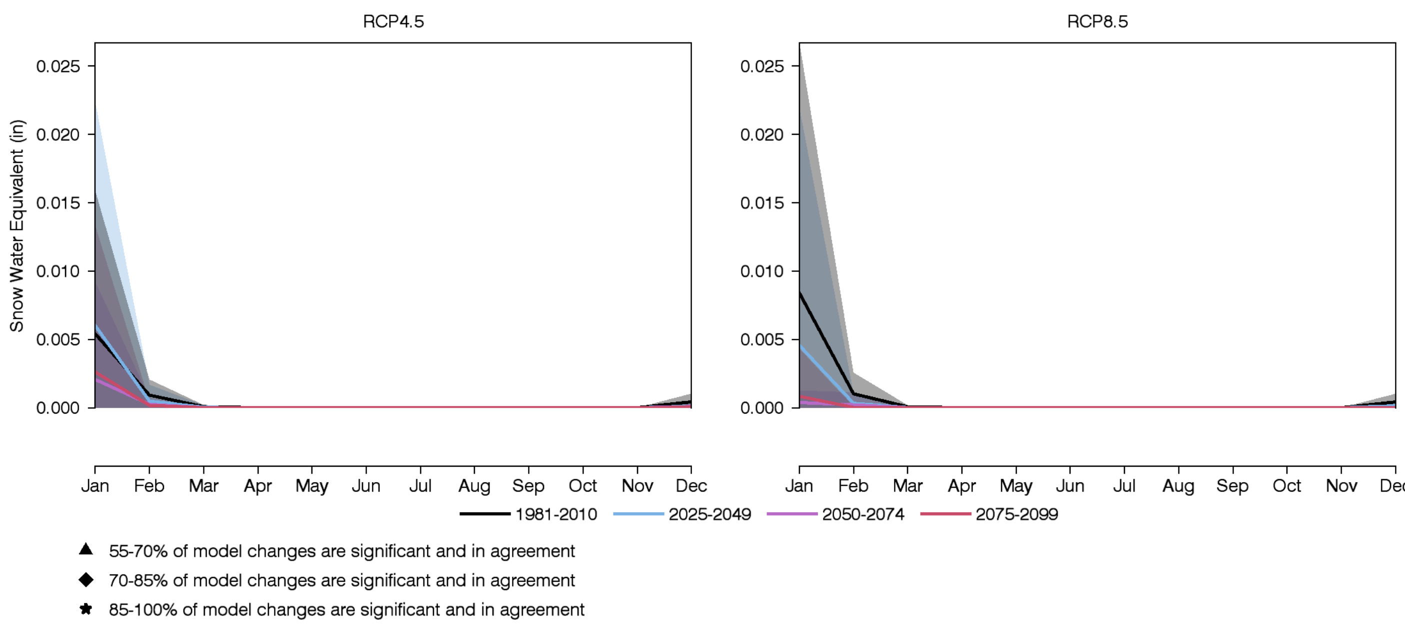


Figure 8: Monthly averages of snow water equivalent for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

5 Runoff

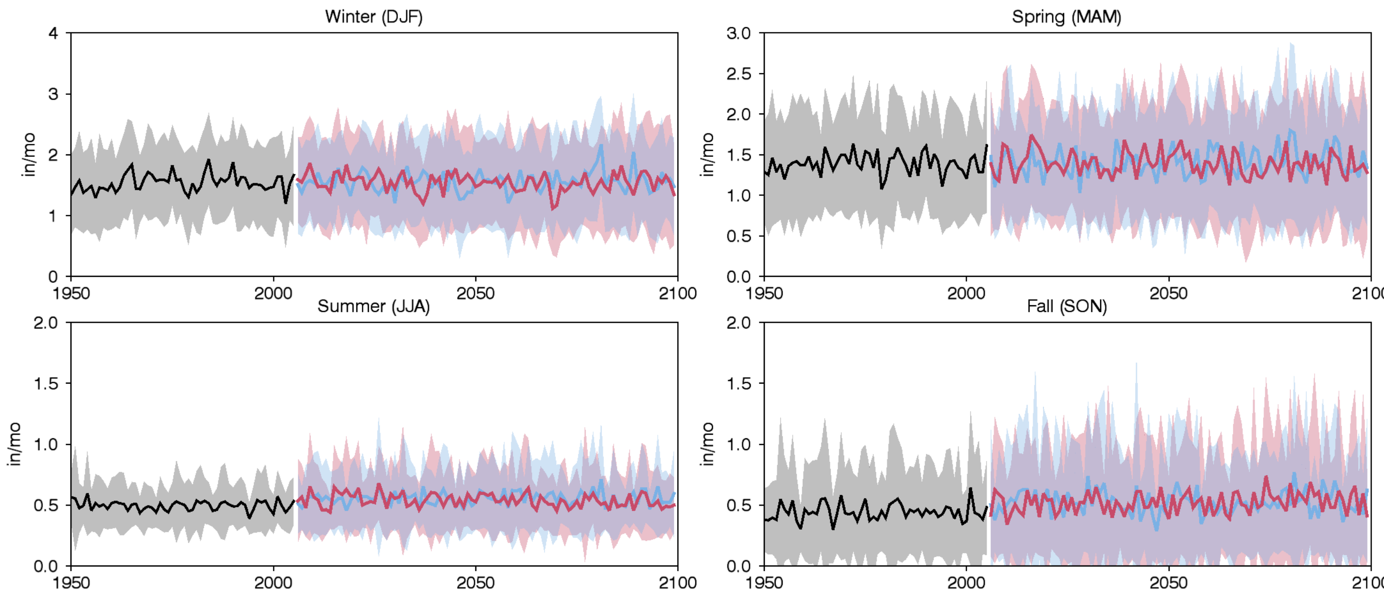


Figure 9: Seasonal average time series of runoff for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

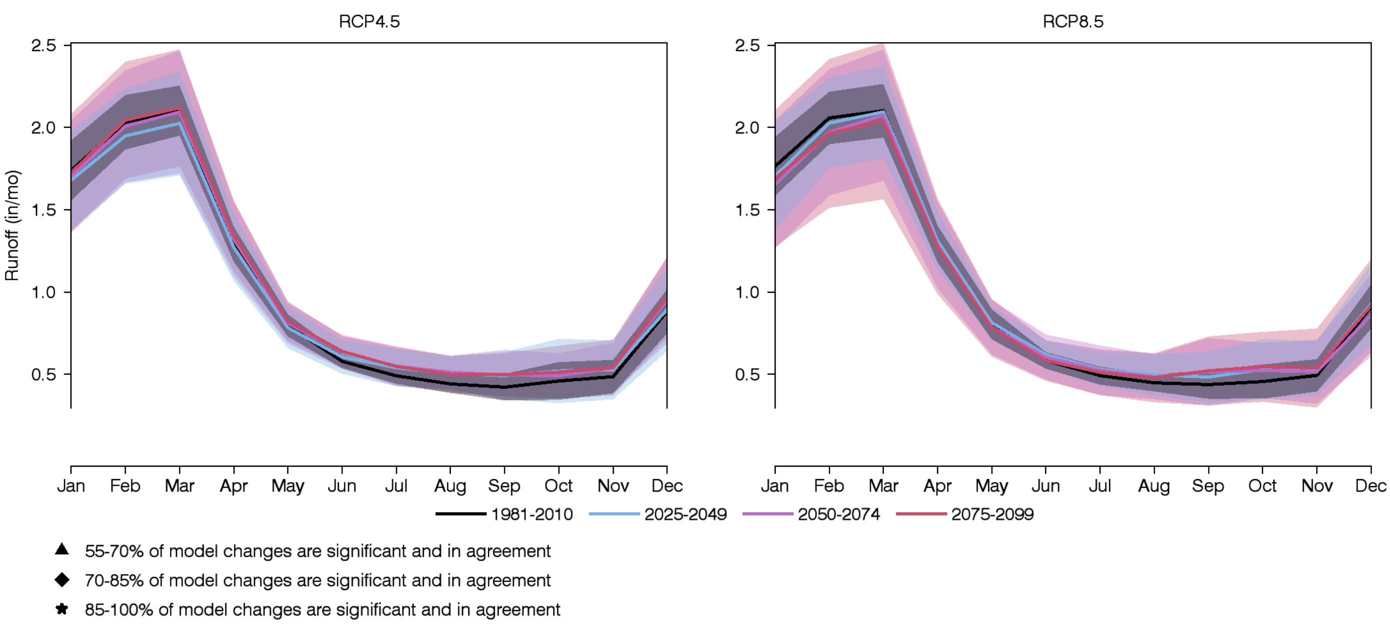


Figure 10: Monthly averages of runoff for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

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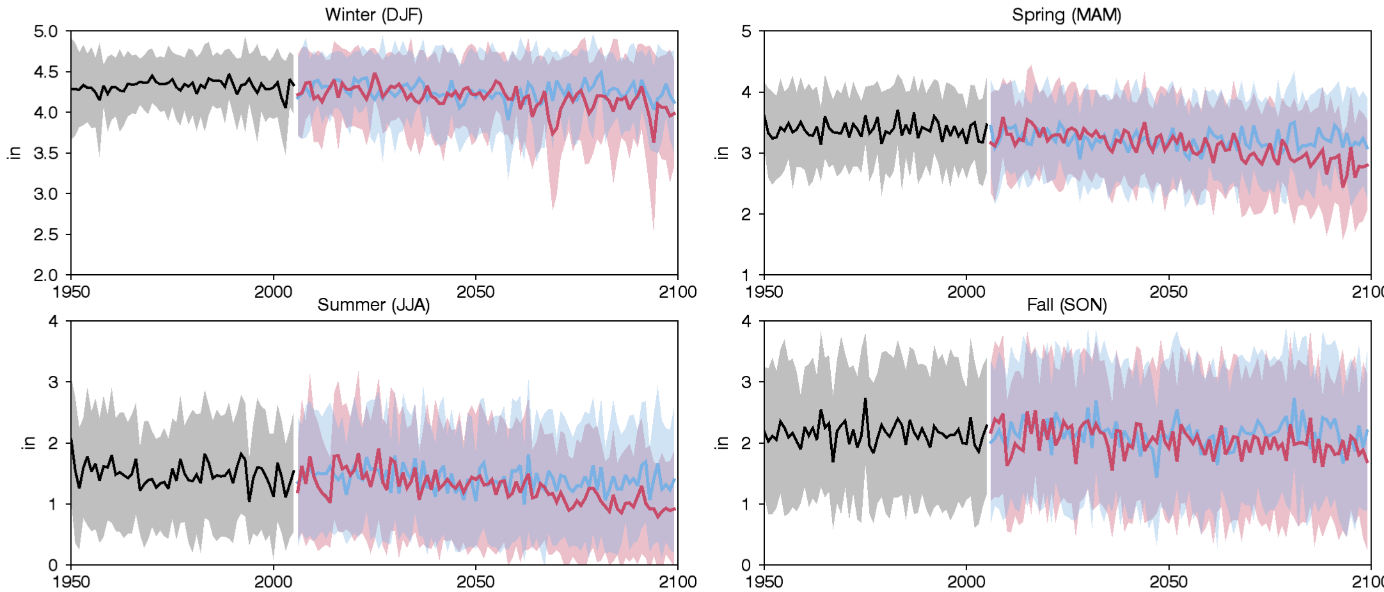

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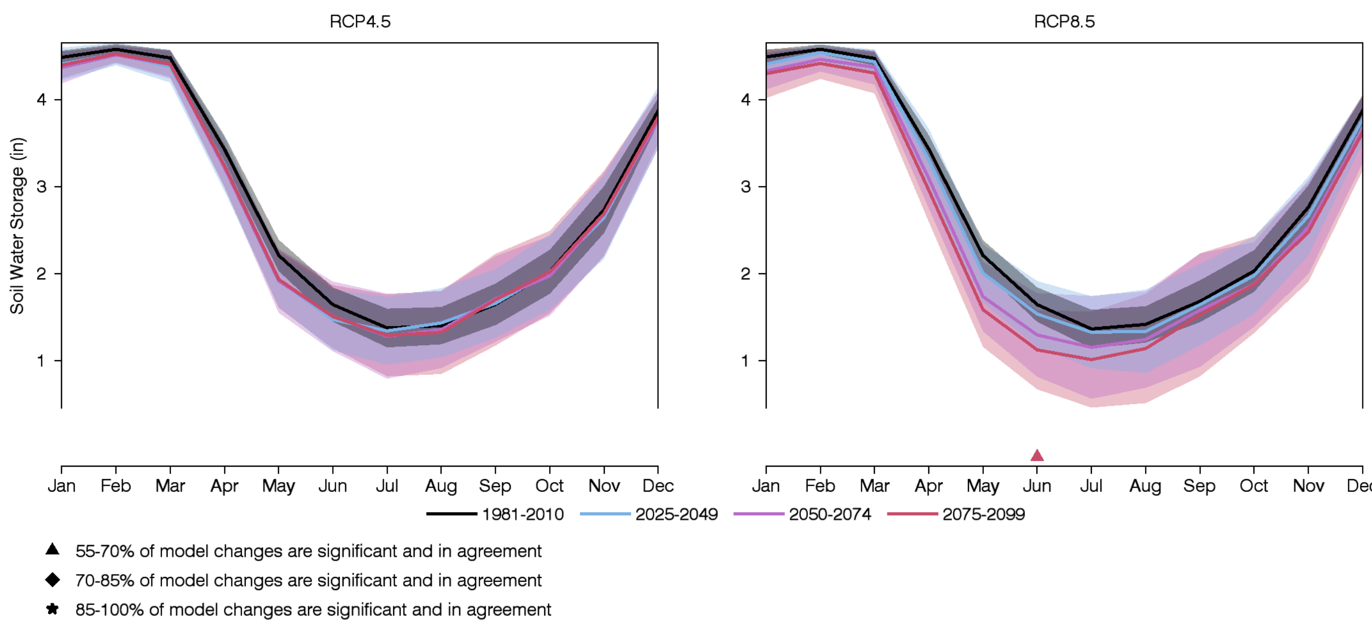

Figure 12: Monthly averages of soil water storage for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

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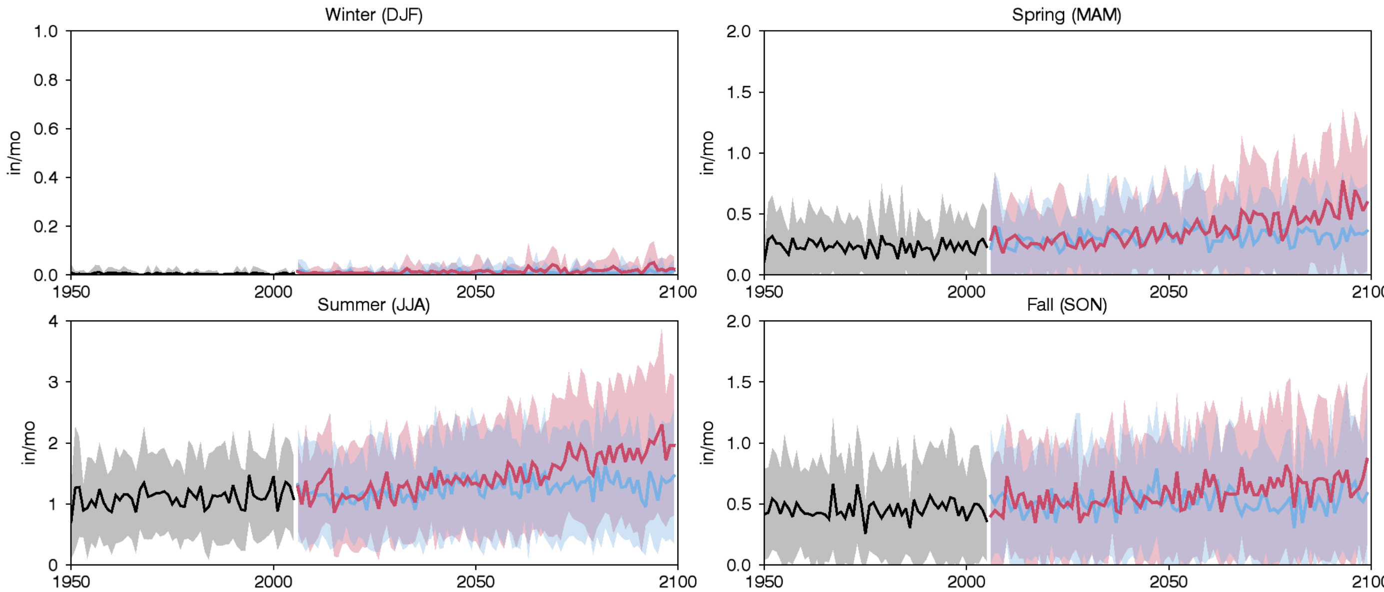

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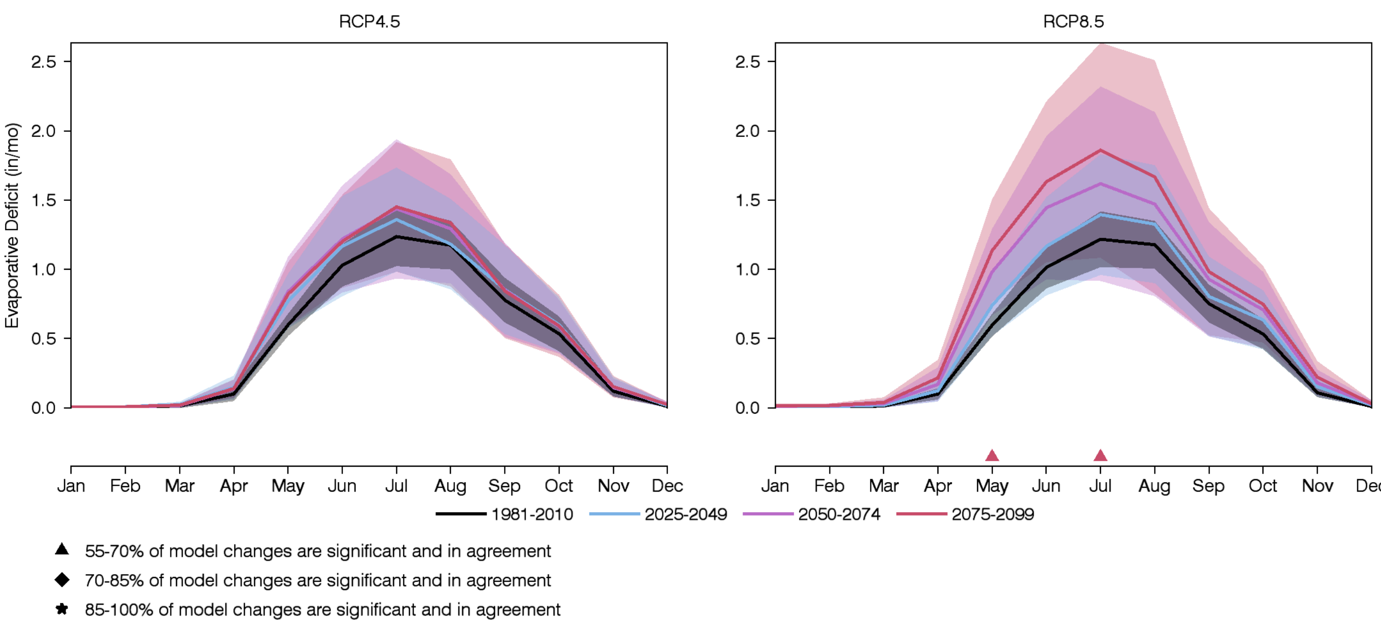

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CESM1-BGC	CMCC-CM	CNRM-CM5	CSIRO-Mk3-6-0	FGOALS-g2	FIO-ESM
GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M	GISS-E2-R	HadGEM2-AO	HadGEM2-CC
HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5
MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MPI-ESM-MR	MRI-CGCM3	NorESM1-M

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Appendix 5

Protected status of current populations throughout the range of the dwarf-flowered heartleaf. Protected status is as follows: 1-protected in perpetuity; 2-protected, but not in perpetuity; 3-not protected.

Population Number	Protection Status
1	1
2	1
3	1
23	3
29	3
31	2 (part)
2	2 (part)
44	1
59	2(part)
77	1
93	3
96	1 (part)
98	3
99	2 (part)
100	1 (part)
125	2
154	1
157	3
158	2/3
176	3
177	3
178	2
179	2(part)
206	3
208	2
214	2 (part)
216	2 (part)
217	1
227	1
232	3
243	1/2 (part)
245	2/3
247	1 (part)
248	3
252	?
271	1
272	3
274	3
275	3
276	2
279	3
287	1
291	2(part)
292	3

293	3
295	2 (part)
296	3
297	3
298	3
299	3
300	3
302	1 (part)
303	1/2
304	1
306	3
308	2 (part)
309	3
311	1
312	1
316	?
317	3
318	2 (part)
320	3
321	3

Appendix 6

North Carolina

EO_Code	Abundance Category	MAXENT Average MEAN	Maxent Classified Percent 0.8 - 1	80% or greater SLEUTH Percent Percent of Total
1	2	34	1	3
5	2	21	0	0
8	1	27	0	6
17	1	50	13	0
18	1	36	8	2
25	1	47	15	30
33	2	33	3	0
48	1	14	0	12
57	2	21	0	80
58	1	42	5	0
64	2	39	9	11
69	2	46	11	19
70	2	38	1	0
72	2	52	14	0
83	2	17	0	11
84	2	13	0	1
89	2	13	2	0
92	2	15	0	30
118	3	42	0	9
151	2	16	0	27
180	2	21	1	0
187	2	20	1	35
188	2	24	0	53
194	4	51	14	18
207	2	33	2	85
230	1	54	15	13

South Carolina

EO_Code	Abundance Estimate	MAXENT Average MEAN	Maxent Classified Percent 0.8 - 1	80% or greater SLEUTH Percent Percent of Total
1	33	67	14	100
2	33	2	0	96
4	0	42	3	90
5	33	0	0	36
6	0	0	0	64
8	33	0	0	86

13	0	22	0	0
15	0	0	0	96
19	0	37	0	35
20	33	16	0	0
21	100	15	0	10
22	0	0	0	100
24	0	13	0	97
25	0	44	0	52
30	33	22	0	12
32	33	22	0	7
33	33	5	0	80
34	0	100	100	99
35	0	74	34	47
36	33	18	0	100
37	0	78	66	100
38	100	16	0	63
39	0	18	0	99
40	33	17	0	80
41	0	36	0	13
42	33	9	0	94
43	0	72	0	57
46	0	31	0	4
49	67	26	0	30
50	33	16	0	46
51	0	0	0	65
52	67	0	0	100
53	33	33	0	34
54	33	28	0	9
55	0	12	0	1
56	33	43	0	4
59	33	12	0	83
60	100	53	21	88

From:	Reid, Rebekah N
To:	Marshall, Michael E
Subject:	Re: HENA Drafts
Date:	Thursday, April 26, 2018 8:13:41 AM
Importance:	High

Hey Mike,

I was noticing the file size of the draft document. Did you get confirmation from anyone that they received your email? I think some folks outside of DOI may have trouble receiving over 10 megs.

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

On Mon, Apr 23, 2018 at 2:59 PM, Marshall, Michael <michael_marshall@fws.gov> wrote:

> Good afternoon all!
>
> It's that time....I've attached a draft of the entire SSA for your review. I'll need to send 2 separate emails; the second email will have the appendices. The attached draft includes all sections you have already reviewed with your comments and suggested edits integrated....and, future conditions, which you will be seeing for the first time. One of the biggest changes we made from the last sections you reviewed was to go back a little further in considering what a current population is....and, focusing on the likelihood that those EOs that we did not include, may very will still persist....you'll see statements to that effect, and how we dealt with this in the "rediscovery" of some populations in 2 of our future scenarios.
>
> As far as when we need your comments....we will need your review sent back no later than COB Monday May 7th. This will ensure that we have adequate time to send out for external peer review before we finalize the report.
>
> Thank you so much for your involvement, and everything you've done for the conservation of the species. We look forward to your feedback!
>
> Take care,
>
> Mike
>
> On Thu, Mar 15, 2018 at 10:26 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:
>
>> Hello all,

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> Mike
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> Monday-Thursday --> In Office 7:30-4:30 CST
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From:	Marshall, Michael E
To:	Reid, Rebekah N
Subject:	Re: HENA Drafts
Date:	Thursday, April 26, 2018 9:22:53 AM
Importance:	High

Good morning Rebekah,

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On Thu, Mar 15, 2018 at 10:26 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:

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From:	Marshall, Michael E
To:	Mason, Suzanne; Amoroso, Jame; Matt Estep; tpbassette@ncdot.gov; Endries, Mark; Reid, Rebekah N; Becker, Drew N; Stephanie DeMay
Subject:	Re: HENA Drafts
Date:	Thursday, April 26, 2018 9:30:54 AM
Importance:	High

Good morning all,

In case the file size was too large, I've pasted a google drive link here to access the draft SSA for your review.

Please confirm you were able to access the draft. Thanks so much!

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From:	Reid, Rebekah N
To:	Marshall, Michael E
Subject:	Re: HENA Drafts
Date:	Monday, April 30, 2018 3:23:24 PM
Importance:	High

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Thanks.

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Subject:	Re: HENA Drafts
Date:	Monday, April 30, 2018 3:44:47 PM
Importance:	High

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From: Reid, Rebekah N
To: Marshall, Michael E
Subject: Re: HENA Drafts
Date: Monday, April 30, 2018 4:01:17 PM
Importance: High

OK, I sent an invite to share. Let's see if that works...

Rebekah Reid

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Thank you so much for your involvement, and everything you've done for the conservation of the species. We look forward to your feedback!

Take care,

Mike

On Thu, Mar 15, 2018 at 10:26 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:

Hello all,

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If you have any questions, please let me know.

Thanks!

Mike

On Thu, Feb 22, 2018 at 9:19 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:

Good morning Team!

Sorry for the delay, but here are the next two sections of the HENA SSA attached for your consideration and review, with appendices attached as well. These sections are Current Conditions and Influences on Viability. As you review and provide comments on these sections, we will be working on the Future Conditions section, which will be the final section of the SSA.

Please provide your edits and comments to these documents in track changes by **COB Friday March 2nd.**

Thanks you so much for your help and input on all of this. And, if at any time you have any questions, please feel free to contact me or Rebekah.

Take care and have a great weekend!

Mike

--

Mike Marshall
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Cell: 512-461-6217
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Work Schedule 1st Week
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From:	Marshall, Michael E
To:	Reid, Rebekah N
Subject:	Re: HENA Drafts
Date:	Monday, April 30, 2018 4:07:35 PM
Importance:	High

Yep...got it! Thanks!

Mike

On Mon, Apr 30, 2018 at 4:01 PM, Reid, Rebekah <rebekah_reid@fws.gov> wrote:

> OK, I sent an invite to share. Let's see if that works...
>
> 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.***
>
> On Mon, Apr 30, 2018 at 3:44 PM, Marshall, Michael <michael_marshall@fws.gov> wrote:
>
>> Hello Rebekah!
>>
>> It seems I cannot access the file....not sure why. Any way you could email it to me?
>>
>> Thanks,
>>
>> Mike
>>
>> On Mon, Apr 30, 2018 at 3:23 PM, Reid, Rebekah <rebekah_reid@fws.gov> wrote:
>>
>>> Hey Mike,
>>>
>>> I read the entire SSA today. I added my comments to the document Mark commented on, hopefully, to make it easier...preventing duplicate or contradicting comments. It's in the Final Draft folder. Let me know if you have any questions or don't see the document in Drive.
>>>
>>> Thanks.
>>>
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On Thu, Apr 26, 2018 at 9:22 AM, Marshall, Michael <michael_marshall@fws.gov> wrote:

> Good morning Rebekah,
>
> I did not....I'll send out another email, this time with a google drive link in case the file is to big.
>
> Thanks!
>
> Mike
>
> On Thu, Apr 26, 2018 at 8:13 AM, Reid, Rebekah <rebekah_reid@fws.gov> wrote:
>
>> Hey Mike,
>>
>> I was noticing the file size of the draft document. Did you get confirmation from anyone that they received your email? I think some folks outside of DOI may have trouble receiving over 10 megs.
>>
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>>
>> US Fish and Wildlife Service
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Appendix B3: NC Natural Heritage Program (NCNHP) Element Occurrence Rank Specifications for *Hexastylis naniflora*

"A" Rank Specifications (excellent viability)
An A-ranked population of *Hexastylis naniflora* should have more than 500 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest.

“B” Rank Specifications (good viability)
A B-ranked population of *Hexastylis naniflora* should have 200-500 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - more than 500 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

"C" Rank Specifications (fair viability)
A C-ranked population of *Hexastylis naniflora* should have 100-200 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - 200- 500 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

"D" Rank Specifications (poor viability)
A D-ranked population of *Hexastylis naniflora* should have fewer than 100 clumps (rosettes) occurring in greater than one acre of high quality forest such as Dry-Mesic Oak Hickory Forest or Mesic Mixed Hardwood Forest - OR - less than 200 clumps occurring in less than one acre of high quality forest or on land impacted by human disturbance such as logging, grazing, mowing, etc.

“E” Rank Specifications (extant)
An E-ranked population of *Hexastylis naniflora* is an occurrence that has recently been verified as still existing, but sufficient information for the factors used to estimate viability has not yet been obtained.

“H” Rank Specification (historical)
An H-ranked population of *Hexastylis naniflora* lacks recent field information verifying the continued existence of the occurrence. In the absence of known disturbance and with the habitat still extant, H is generally recommended for occurrences that have not been reconfirmed for approximately 30 or more years.

“F” Rank Specification (failed to find)
An F-ranked population of *Hexastylis naniflora* has not been found despite a search by an experienced observer at a time and under conditions appropriate for the Element at a location where it was previously reported, but the occurrence still might be confirmed to exist at that location with additional field survey efforts. For occurrences with vague locational information, the search must include areas of appropriate habitat within the range of locational uncertainty.

“X” Rank Specification (failed to find)
An X-ranked population of *Hexastylis naniflora* is considered destroyed based on adequate surveys by one or more experienced observers at times and under conditions appropriate for the species at the occurrence location, or other persuasive evidence indicates that the species no longer exists there or that the habitat has been destroyed to such an extent that it can no longer support the species.

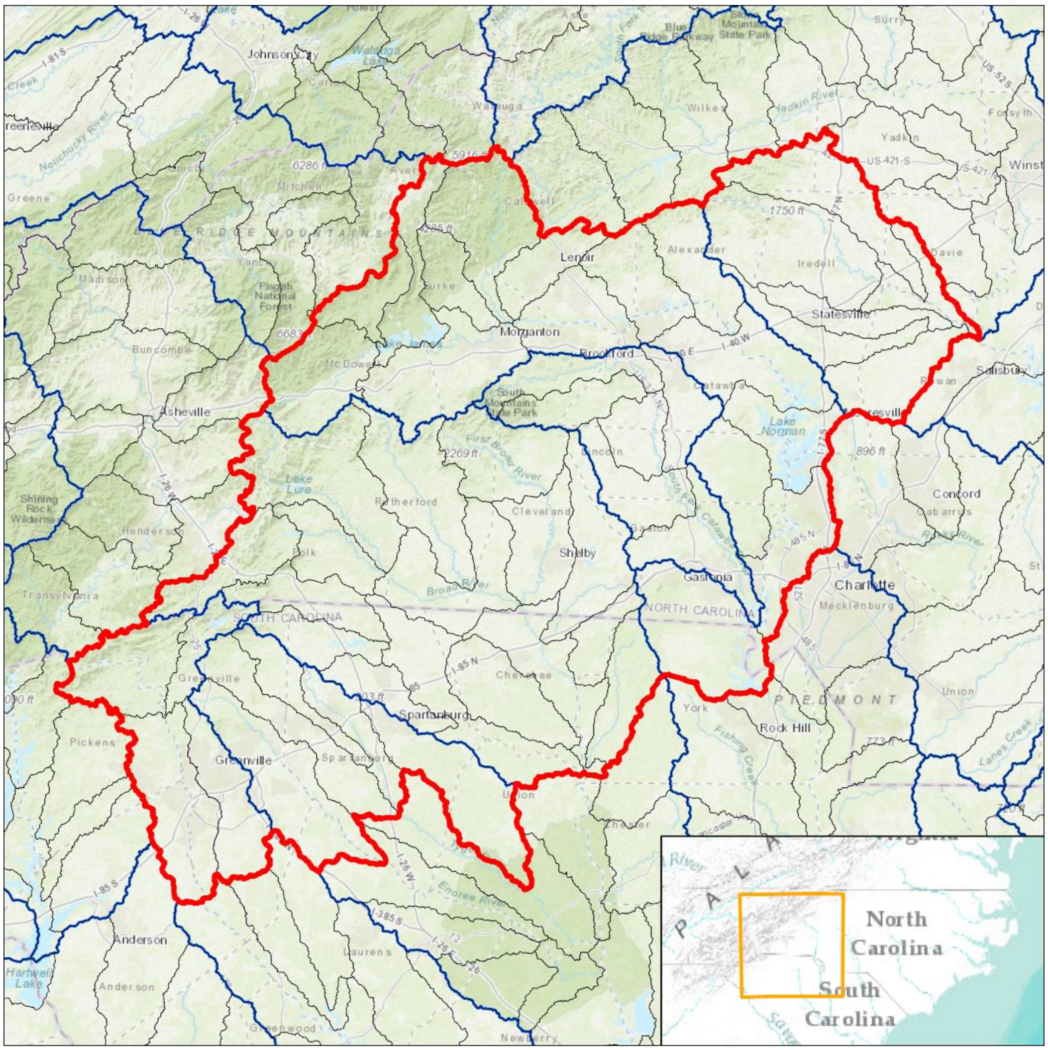
"U" Rank Specification (failed to find)
A U-ranked population of *Hexastylis naniflora* cannot be assigned a rank due to lack of sufficient information on the occurrence or the species identification has not been confirmed.

Rank Specifications Justification
The unit of measurement for population size in this species is "clump" (rosette). EO size (as quantified by number of clumps or rosettes) is the primary rank factor. Condition of habitat (vegetation community and structure) and Landscape context (extent of suitable habitat and physical factors) are also incorporated secondarily. The species thrives most in undisturbed habitat. However, disturbed lands, that have been logged, grazed, mown, or converted to pasture, orchards, or tree plantations have been found to support remnant patches of *Hexastylis naniflora*. The extent to which this species can withstand disturbance is unknown. Populations in disturbed habitat are considered at risk, with relatively poor viability (C or D). Care should be taken when estimating population size, as population estimates have been found to vary widely from the number counted in population censuses. Specifications are based on largest known populations and expert opinion (including James Padgett, Carolyn Wells, Misty Buchanan (formerly Franklin), and Brenda Wichmann).

Appendix 2: Maxent Habitat Modelling for Dwarf-flowered Heartleaf

Analysis Extent:

Figure 1. Analysis extent. 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



Coordinate System: USA Contiguous Albers Equal Area Conic USGS version

Cell Size: 30 x 30 meters derived from the USGS National GAP Landcover

Source Datasets Used:

USGS National GAP Landcover - The GAP National Terrestrial Ecosystems – Ver 3.0 is a 2011 update of the National Gap Analysis Program Land Cover Data – Version 2.2 for the conterminous U.S. The GAP National Terrestrial Ecosystems – Version 3.0 represents a highly thematically detailed land cover map of the U.S at a 30 x 30 meter pixel resolution. The map legend includes types described by NatureServe's Ecological Systems Classification (Comer et al. 2002) as well as land use classes described in the National Land Cover Dataset 2011 (Homer et al. 2015). These data cover the entire continental U.S. and are a continuous data layer. The land cover map identifies 49 different land cover types within the range of Hexastylis Naniflora.

SSURGO Soils - The SSURGO database contains information about soil as collected by the National Cooperative Soil Survey over the course of a century. The information was gathered by walking over the land and observing the soil. Many soil samples were analyzed in laboratories. The maps outline areas called map units. The map units describe soils and other components that have unique properties, interpretations, and productivity. The information was collected at scales ranging from 1:12,000 to 1:63,360.

National Elevation Dataset - The NED is a seamless dataset with the best available raster elevation data of the conterminous United States, Alaska, Hawaii, and territorial islands. The NED is derived from diverse source data that are processed to a common coordinate system and unit of vertical measure. NED data are available nationally (except for Alaska) at resolutions of 1 arc-second (about 30 meters) and 1/3 arc-second (about 10 meters), and in limited areas at 1/9 arc-second (about 3 meters). The 1/3 arc-second database was used for HENA modelling purposes.

PRISM Climate Data - The PRISM Climate Group gathers climate observations from a wide range of monitoring networks, applies sophisticated quality control measures, and develops spatial climate datasets to reveal short- and long-term climate patterns. The resulting datasets incorporate a variety of modeling techniques and are available at multiple spatial/temporal resolutions, covering the period from 1895 to the present.

Model Variables Created:

Landcover – Landcover represented by the default landcover classification (Table 1).

Landcover Hexastylis Grouping – Landcover represented by a grouping of landcover types. For the purposes of discussing Hexastylis naniflora habitat, many of the default landcover classifications are similar and could be grouped together. The definition of each landcover classification was reviewed and categorized using a much broader habitat definition (Table 1).

Table 1. Landcover classification

Default Landcover Classification	Hexastylis Grouping
Southern Piedmont Glade and Barrens	Barren
Southern Ridge and Valley / Cumberland Dry Calcareous Forest	Barren
Undifferentiated Barren Land	Barren
Cultivated Cropland	Disturbed
Deciduous Plantations	Disturbed
Developed, High Intensity	Disturbed
Developed, Low Intensity	Disturbed
Developed, Medium Intensity	Disturbed
Developed, Open Space	Disturbed
Disturbed/Successional - Grass/Forb Regeneration	Disturbed
Disturbed/Successional - Shrub Regeneration	Disturbed
Evergreen Plantation or Managed Pine	Disturbed
Harvested Forest - Grass/Forb Regeneration	Disturbed
Harvested Forest-Shrub Regeneration	Disturbed
Introduced Upland Vegetation - Annual Grassland	Disturbed
Introduced Upland Vegetation - Shrub	Disturbed
Introduced Upland Vegetation - Treed	Disturbed
Pasture/Hay	Disturbed
Quarries, Mines, Gravel Pits and Oil Wells	Disturbed
Ruderal forest	Disturbed
Southern Appalachian Low Mountain Pine Forest	Evergreen
Southern Appalachian Montane Pine Forest and Woodland	Evergreen
Southern and Central Appalachian Cove Forest	Hardwood
Southern and Central Appalachian Oak Forest	Hardwood
Southern and Central Appalachian Oak Forest - Xeric	Hardwood
Southern Piedmont Mesic Forest	Hardwood
Central and Southern Appalachian Montane Oak Forest	High Elevation
Central and Southern Appalachian Northern Hardwood Forest	High Elevation
Central and Southern Appalachian Spruce-Fir Forest	High Elevation
Southern Appalachian Grass and Shrub Bald	High Elevation
Southern Appalachian Grass and Shrub Bald - Shrub Modifier	High Elevation
Appalachian Hemlock-Hardwood Forest	Mixed
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	Mixed
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	Mixed

Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	Mixed
Southern Ridge and Valley Dry Calcareous Forest	Mixed
Southern Ridge and Valley Dry Calcareous Forest - Pine modifier	Mixed
Open Water (Fresh)	Open Water/Wetland
Southern and Central Appalachian Bog and Fen	Open Water/Wetland
Southern Piedmont/Ridge and Valley Upland Depression Swamp	Open Water/Wetland
Southern Appalachian Granitic Dome	Outcrop
Southern Appalachian Montane Cliff	Outcrop
Southern Appalachian Rocky Summit	Outcrop
Southern Piedmont Cliff	Outcrop
Southern Piedmont Granite Flatrock	Outcrop
South-Central Interior Large Floodplain - Forest Modifier	Riparian
South-Central Interior Small Stream and Riparian	Riparian
Southern Piedmont Large Floodplain Forest - Forest Modifier	Riparian
Southern Piedmont Small Floodplain and Riparian Forest	Riparian

Landcover Diversity – Identifies the number of landcover classes (default classification) within a 10-cell radius (300 meters) of an individual pixel.

Landcover Majority – Identifies the dominant landcover class (default classification) within a 10-cell radius (300 meters) of an individual pixel.

SSURGO mukey – SSURGO soils dataset represented by the Map Unit Key (mukey)

SSURGO Drainage Class – SSURGO soils dataset represented by wettest drainage class. Drainage class refers to the frequency and duration of wet periods in conditions similar to those under which the soil formed.

SSURGO Hydrologic Group – SSURGO soils dataset represented by hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

Elevation – National elevation dataset elevation values. This 10-meter dataset was reclassified to 30-meters.

Aspect 9-class – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, Northeast, East, Southeast, South, Southwest, West, and Northwest.

Aspect 5-class – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, East, South, and West.

Slope – The national elevation dataset represented by degree of slope.

Geomorphons – A pattern recognition analysis that converts a digital elevation dataset into 10 common landform elements: flat, peak, ridge, shoulder, spur, slope, pit, valley, footslope, and hollow. The national elevation dataset was used as the source elevation for the analysis.

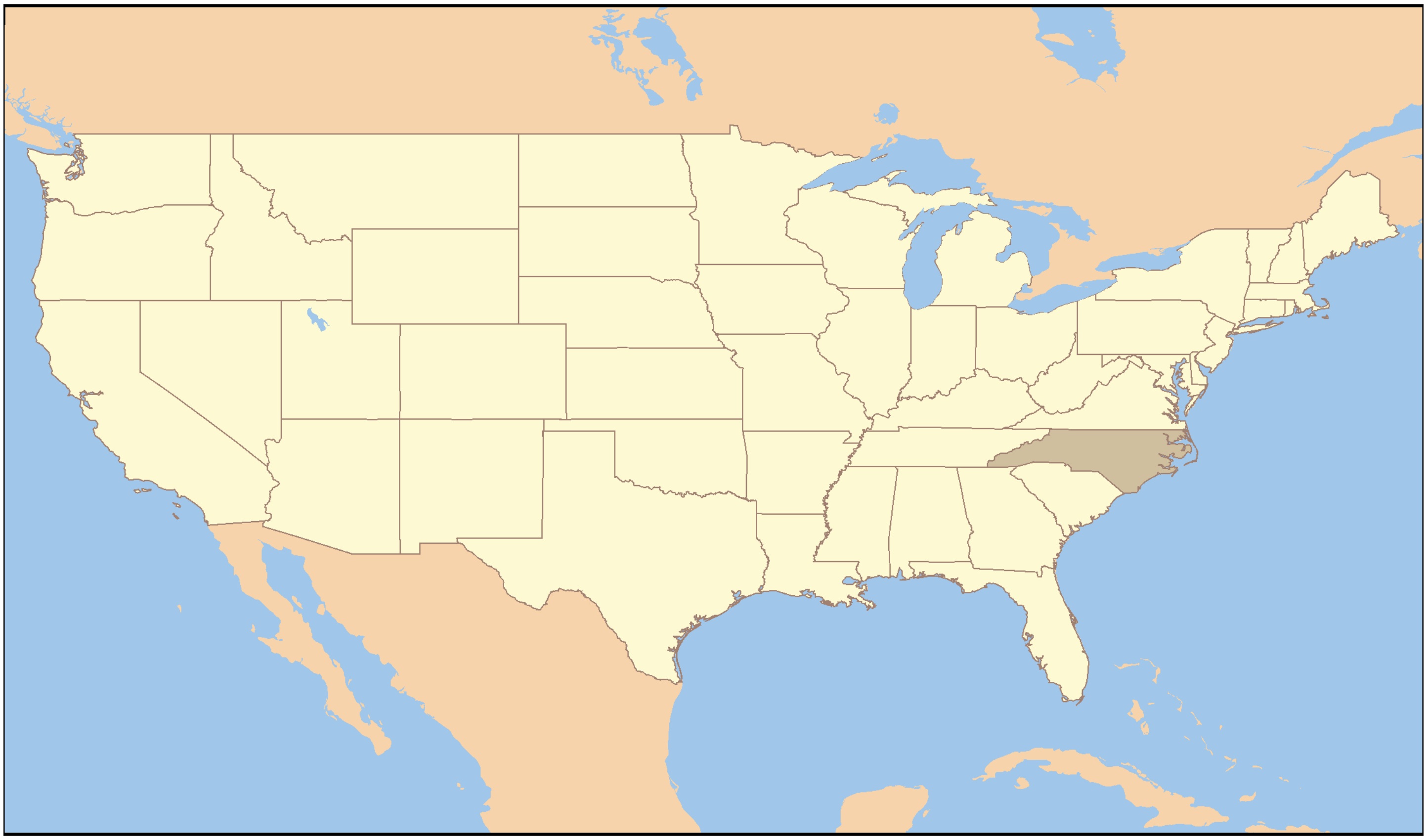
Average Annual Precipitation – Climate dataset of average annual precipitation according to a model using point precipitation and elevation data for the 30-year period of 1971-2000.

Maximum Average Annual Temperature – Climate dataset of average annual maximum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

Minimum Average Annual Temperature – Climate dataset of average annual minimum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

U.S. Geological Survey - National Climate Change Viewer

Summary of North Carolina



December 1, 2016

1 Maximum 2-m Air Temperature

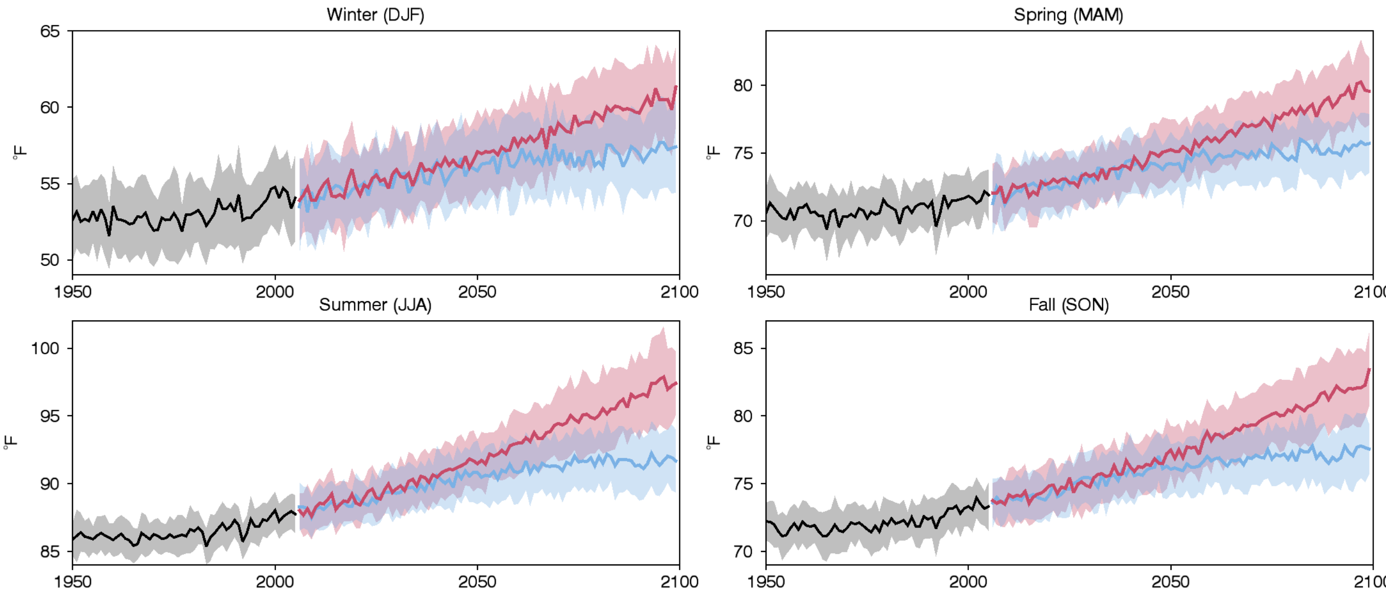


Figure 1: Seasonal average time series of maximum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

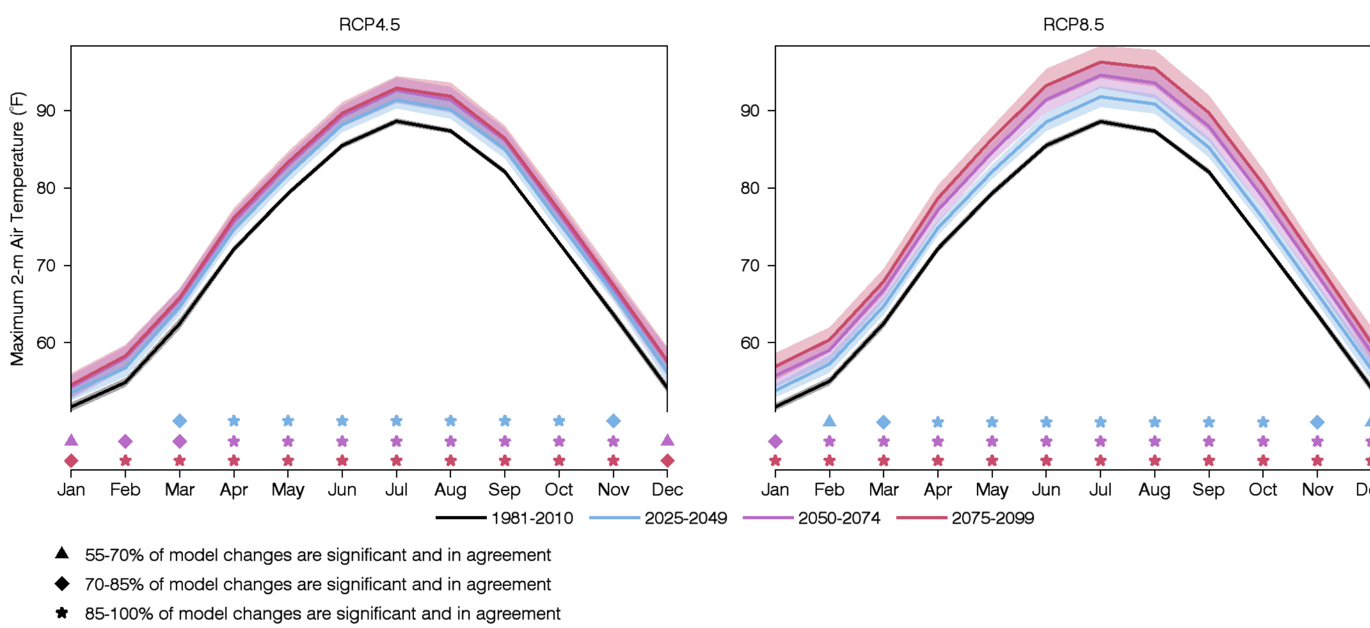


Figure 2: Monthly averages of maximum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

2 Minimum 2-m Air Temperature

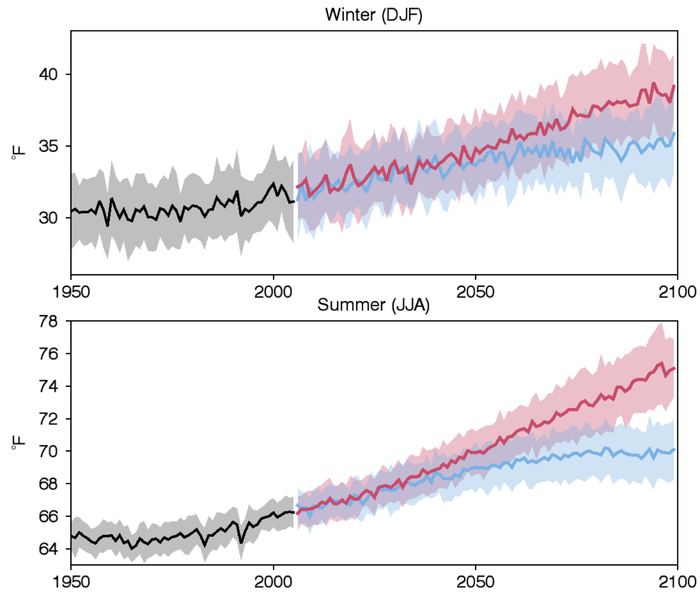


Figure 3: Seasonal average time series of minimum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

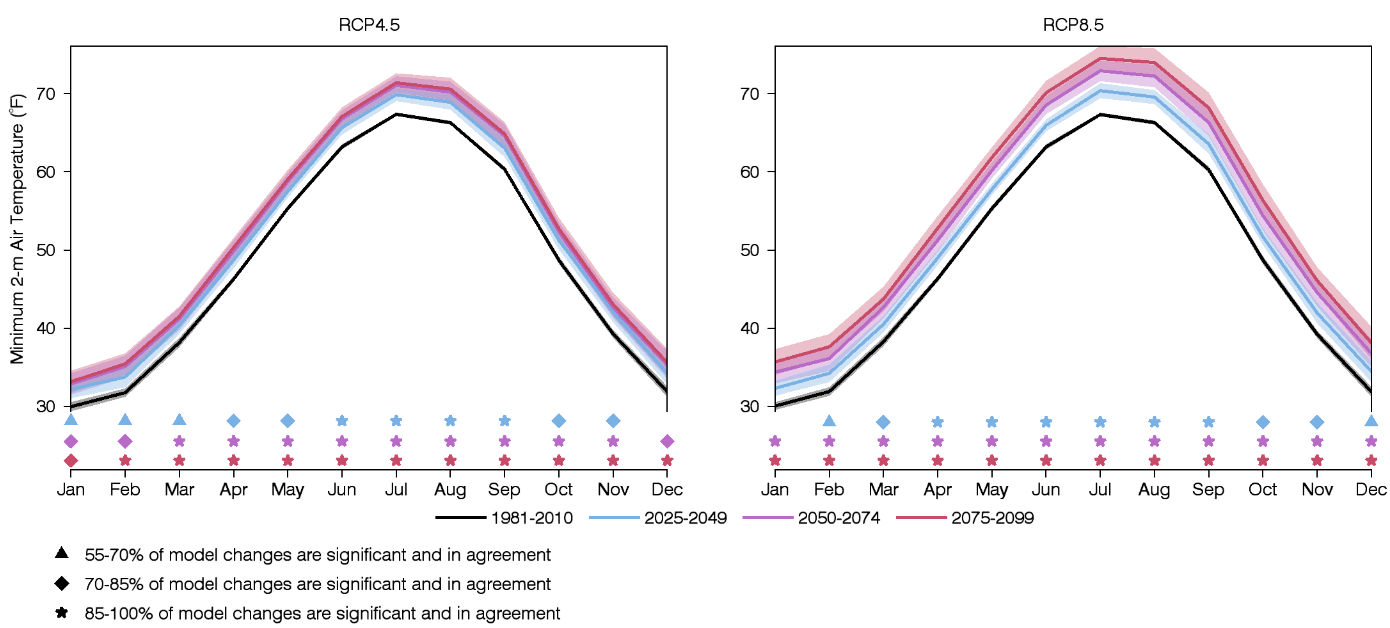


Figure 4: Monthly averages of minimum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

3 Precipitation

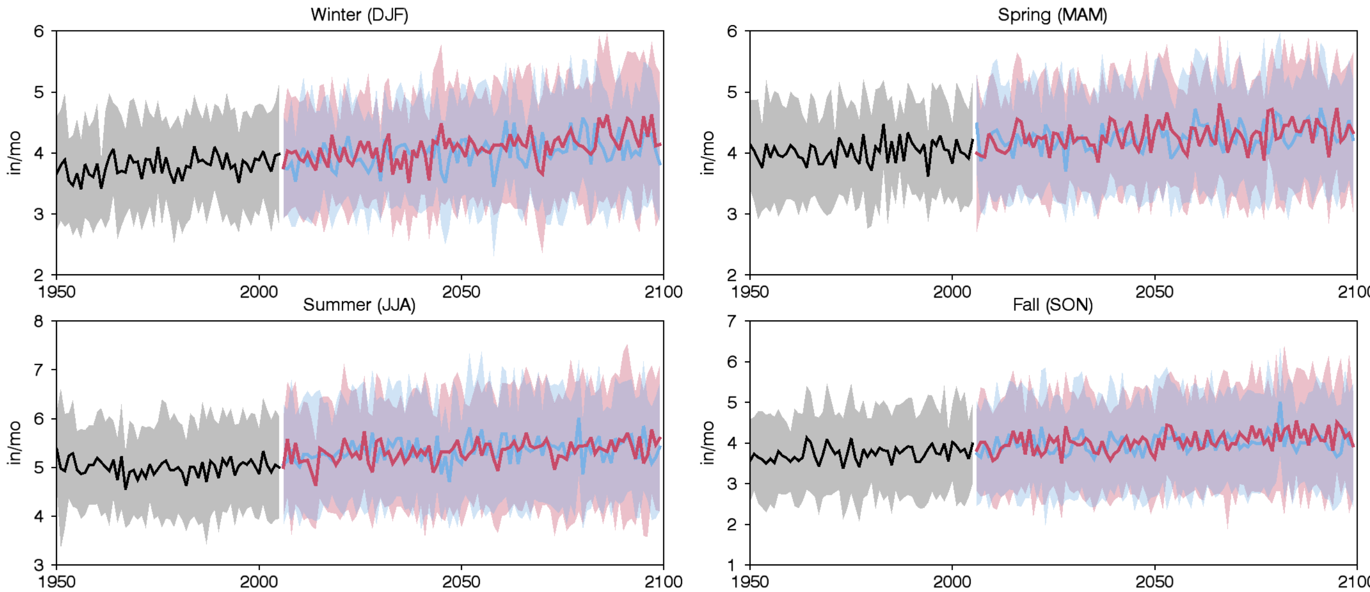


Figure 5: Seasonal average time series of precipitation for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

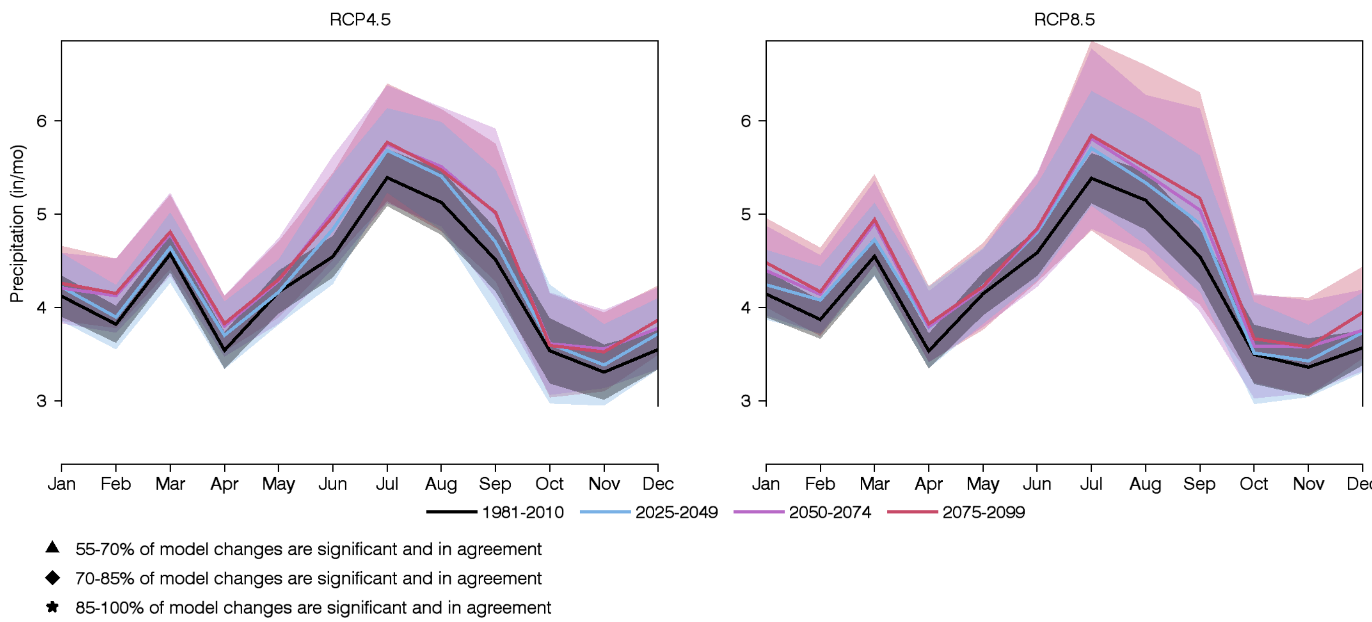


Figure 6: Monthly averages of precipitation for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

4 Snow Water Equivalent

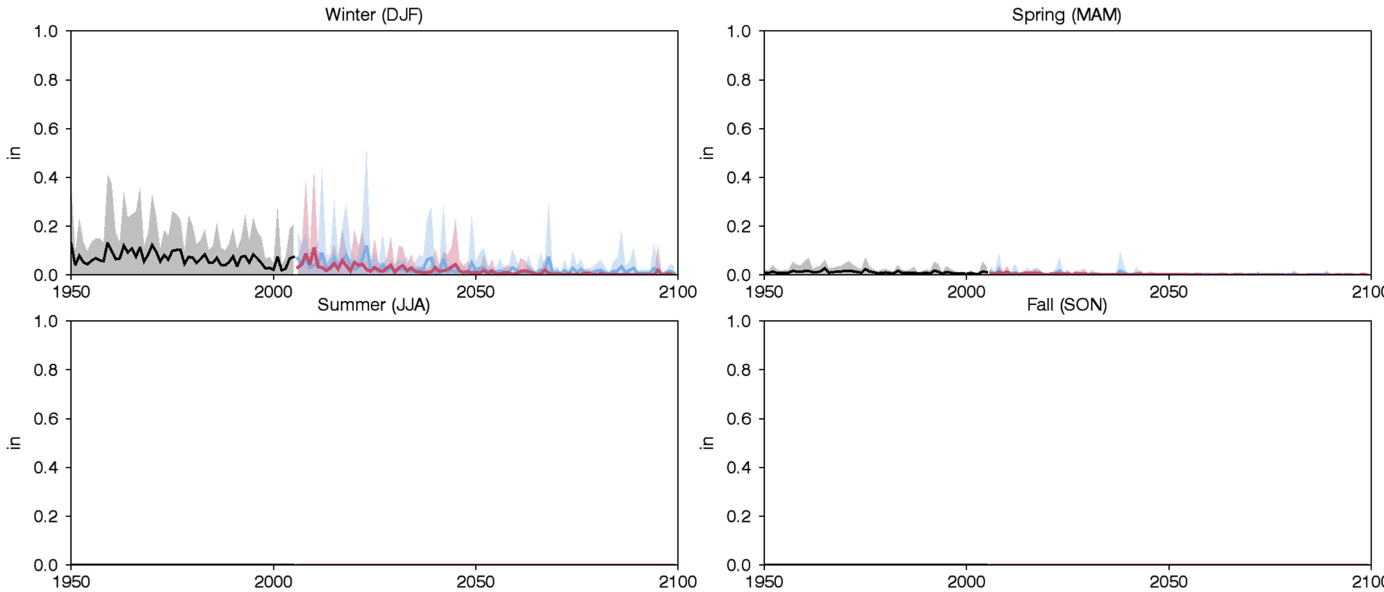


Figure 7: Seasonal average time series of snow water equivalent for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

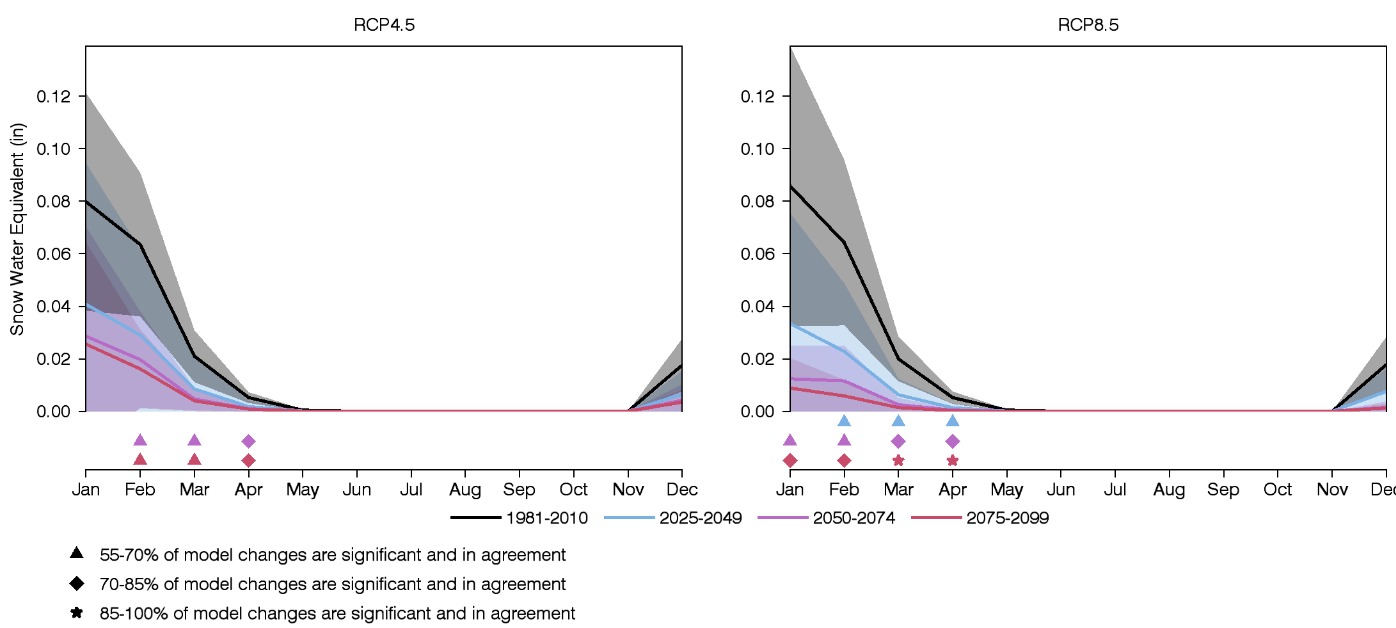


Figure 8: Monthly averages of snow water equivalent for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

5 Runoff

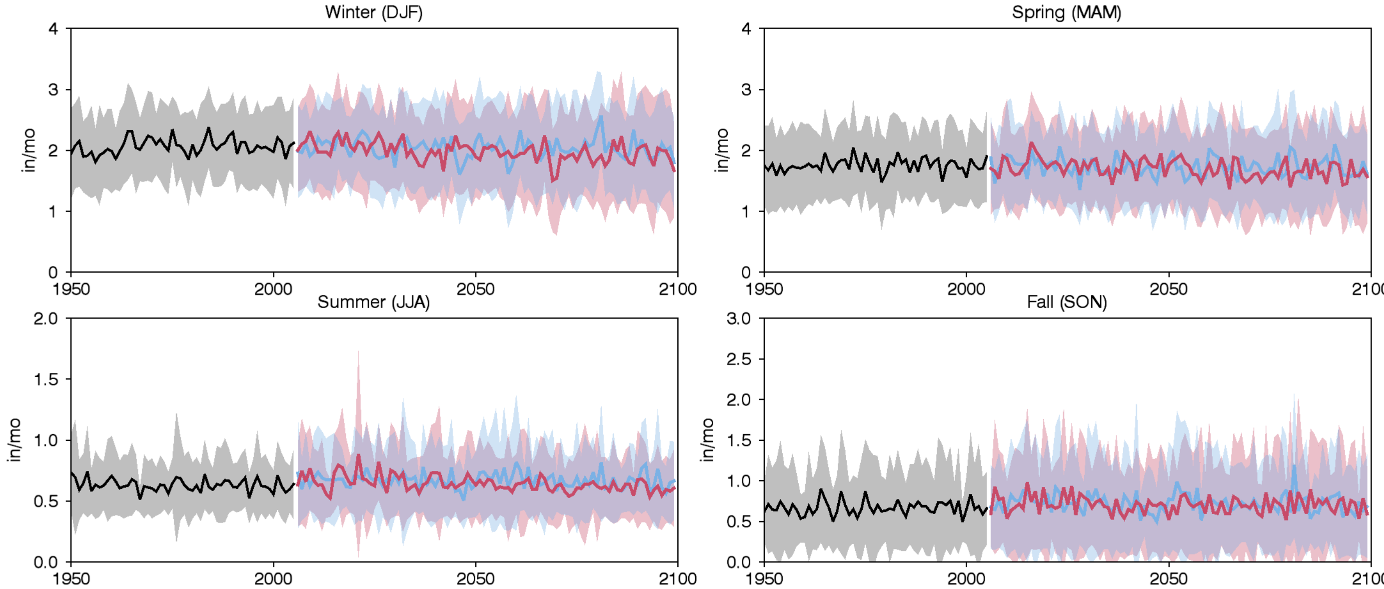


Figure 9: Seasonal average time series of runoff for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

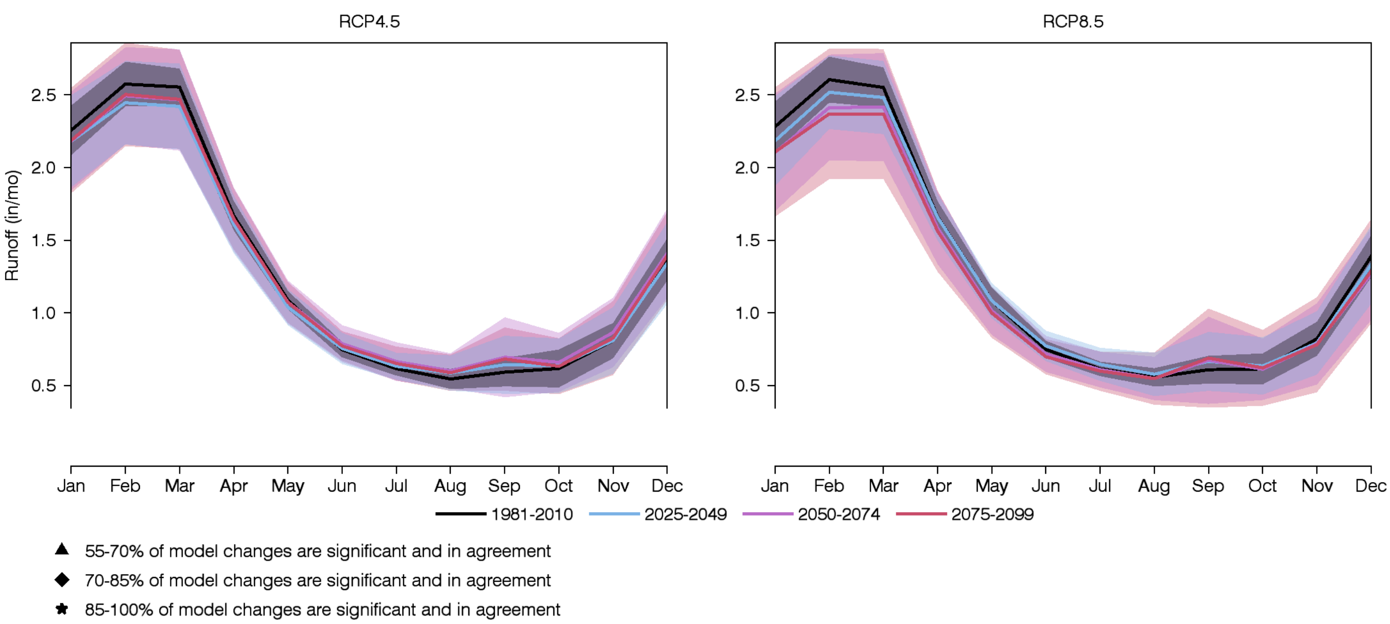


Figure 10: Monthly averages of runoff for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

6 Soil Water Storage

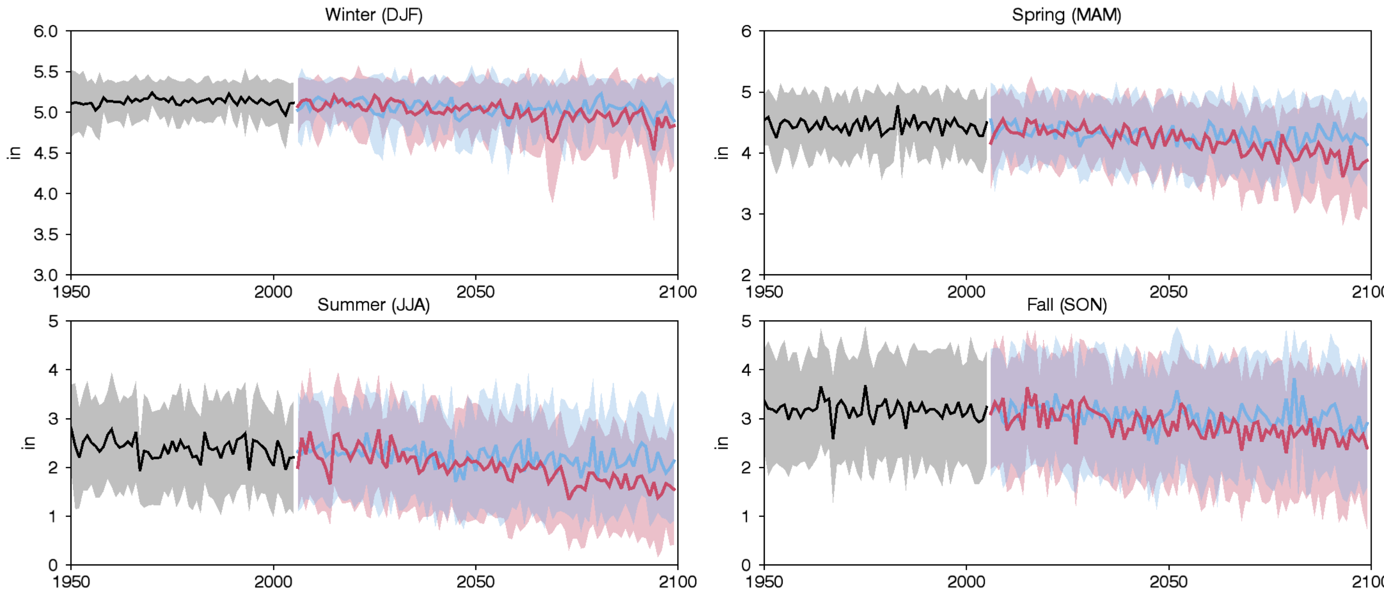


Figure 11: Seasonal average time series of soil water storage for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

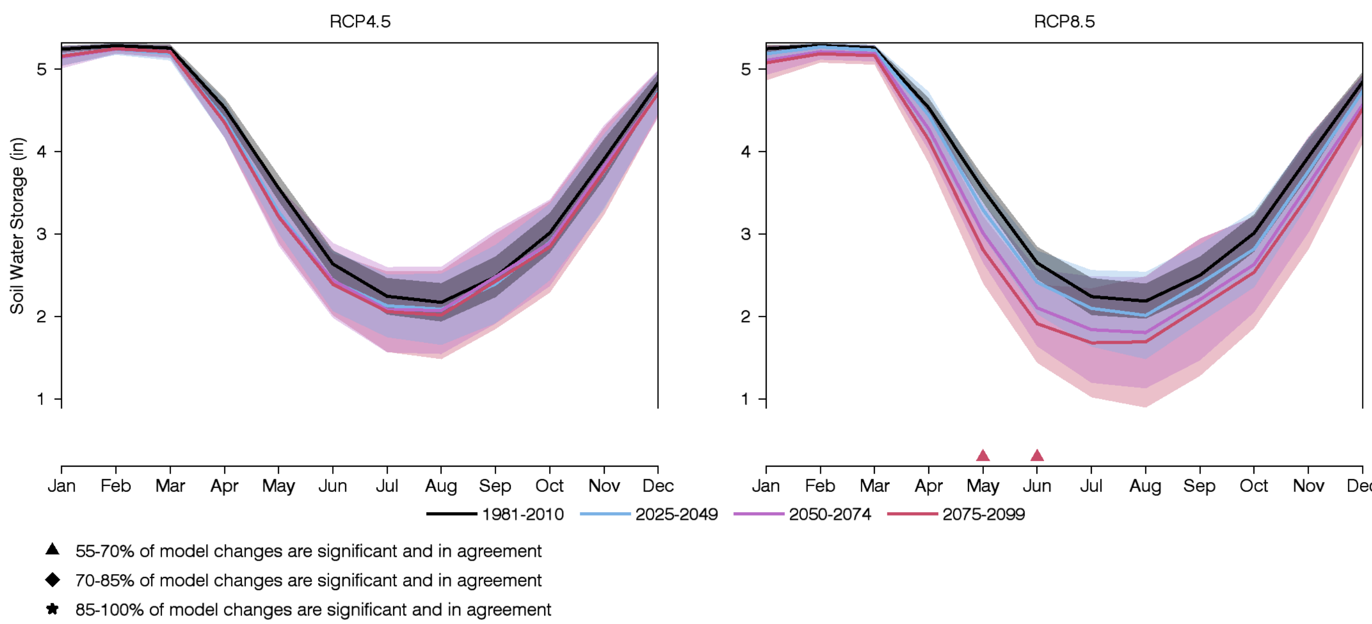


Figure 12: Monthly averages of soil water storage for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

7 Evaporative Deficit

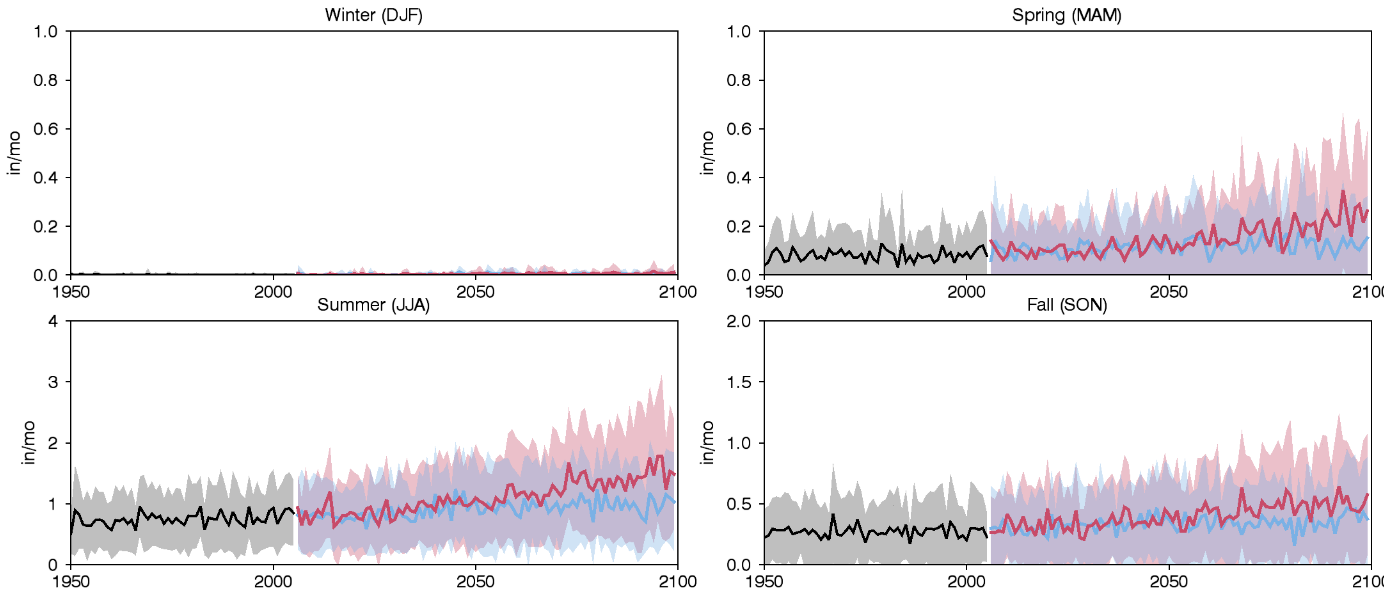


Figure 13: Seasonal average time series of evaporative deficit for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

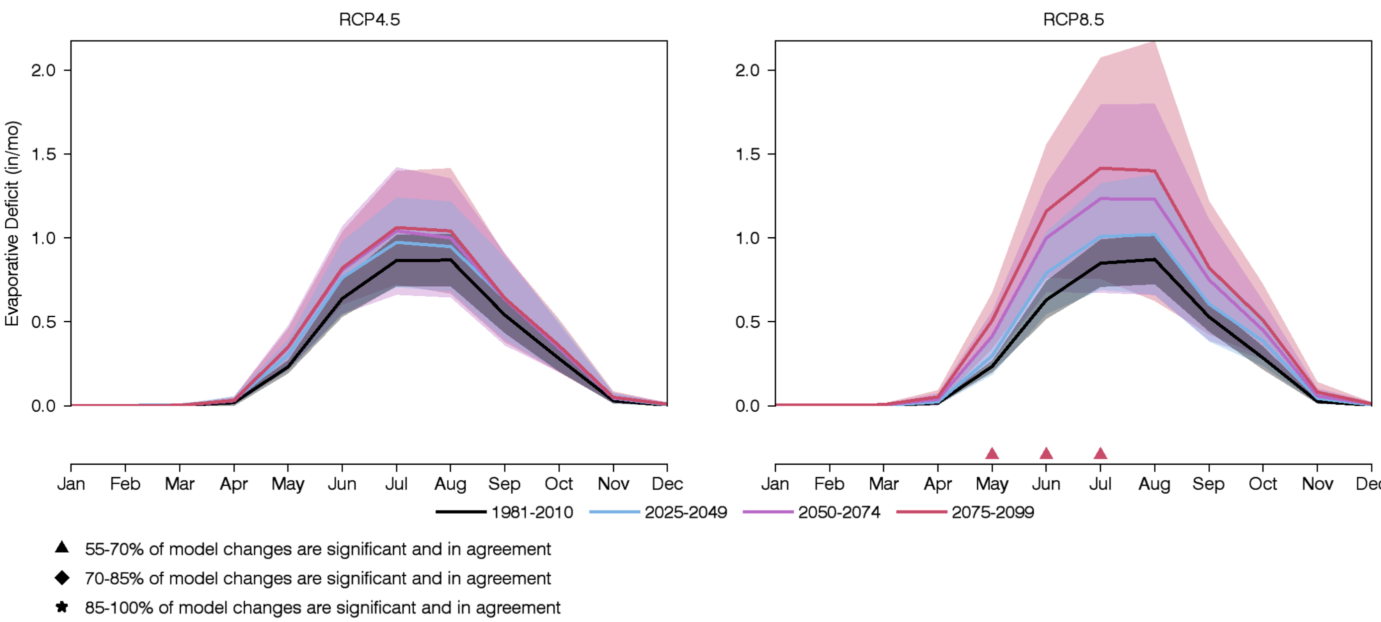


Figure 14: Monthly averages of evaporative deficit for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

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9 Models

ACCESS1-0	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4
CESM1-BGC	CMCC-CM	CNRM-CM5	CSIRO-Mk3-6-0	FGOALS-g2	FIO-ESM
GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M	GISS-E2-R	HadGEM2-AO	HadGEM2-CC
HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5
MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MPI-ESM-MR	MRI-CGCM3	NorESM1-M

10 Citation Information

Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer. US Geological Survey http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp doi:10.5066/F7W9575T.

Hostetler, S.W. and Alder, J.R., 2016. Implementation and evaluation of a monthly water balance model over the U.S. on an 800 m grid. Water Resources Research, 52, doi:10.1002/2016WR018665.

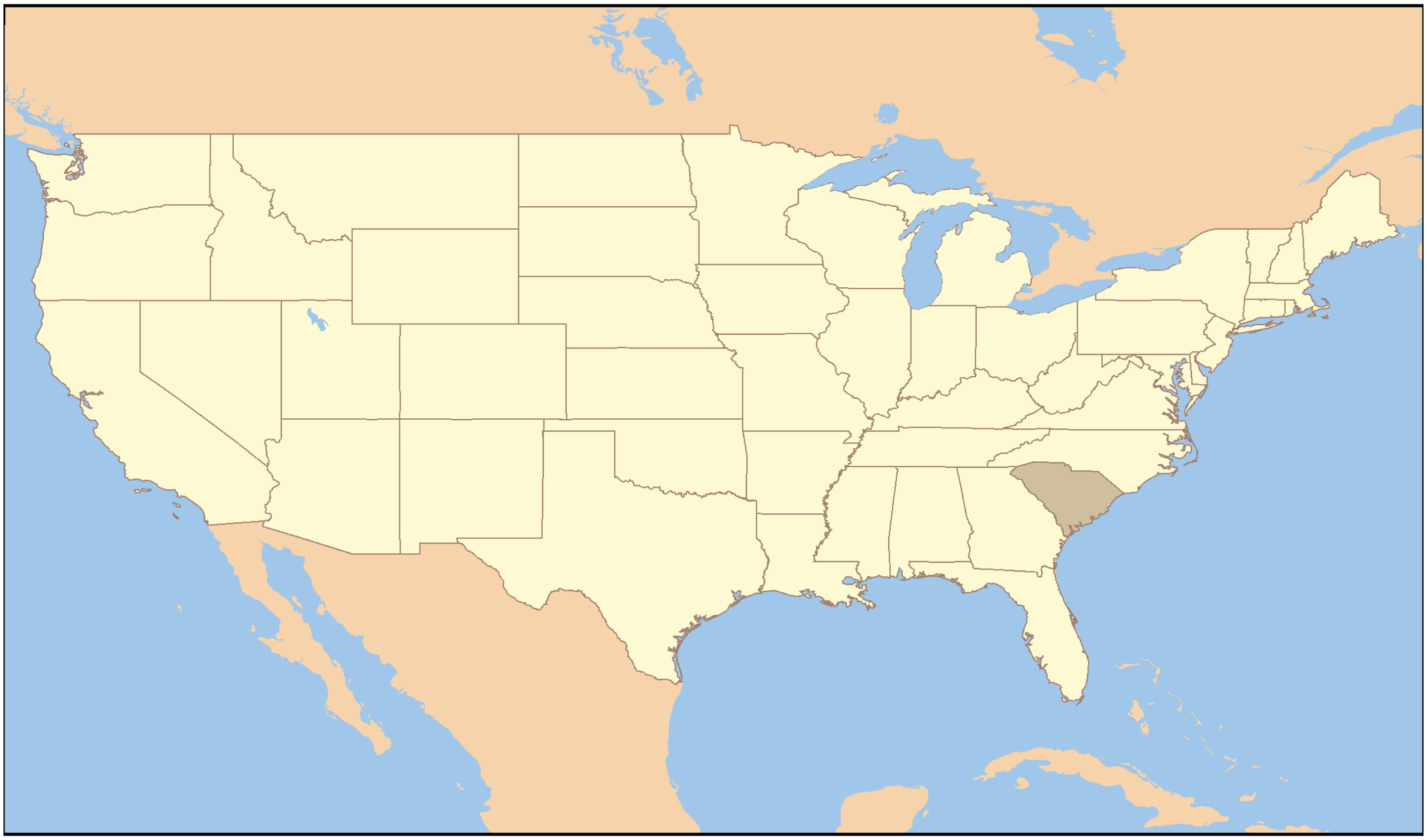
Thrasher, B., J. Xiong, W. Wang, F. Melton, A. Michaelis, and R. Nemani, 2013. New downscaled climate projections suitable for resource management in the U.S. Eos, Transactions American Geophysical Union 94, 321-323, doi:10.1002/2013EO370002.

11 Disclaimer

These freely available, derived data sets were produced by J. Alder and S. Hostetler, US Geological Survey (USGS). The original climate data are from the NEX-DCP30 dataset, which was prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and is distributed by the NASA Center for Climate Simulation. No warranty expressed or implied is made by the USGS regarding the display or utility of the derived data on any other system, or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. The USGS shall not be held liable for improper or incorrect use of the data described and/or contained herein.

U.S. Geological Survey - National Climate Change Viewer

Summary of South Carolina



December 1, 2016

1 Maximum 2-m Air Temperature

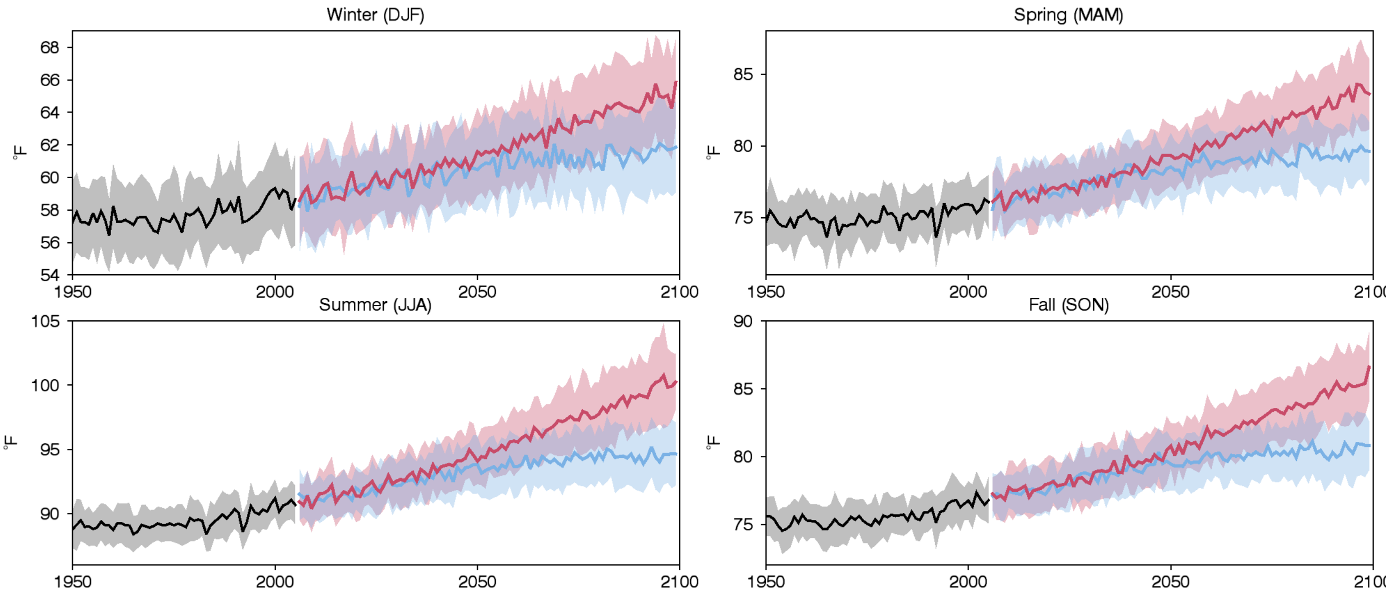


Figure 1: Seasonal average time series of maximum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

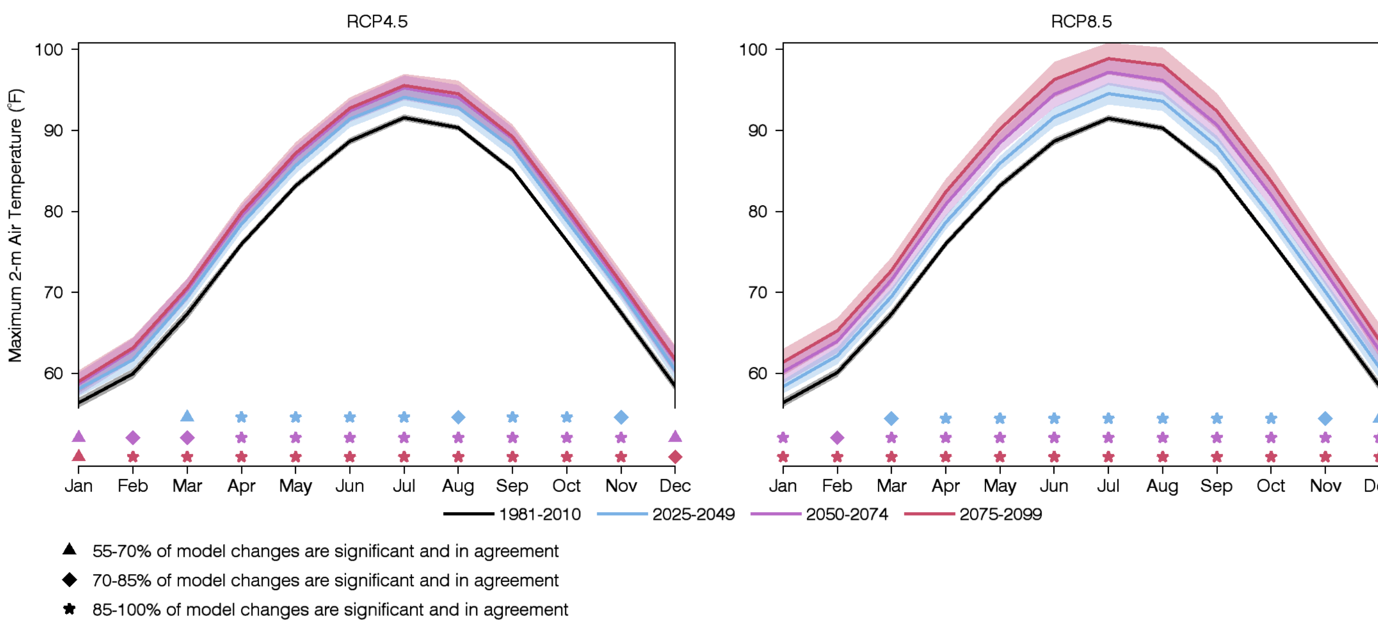


Figure 2: Monthly averages of maximum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

2 Minimum 2-m Air Temperature

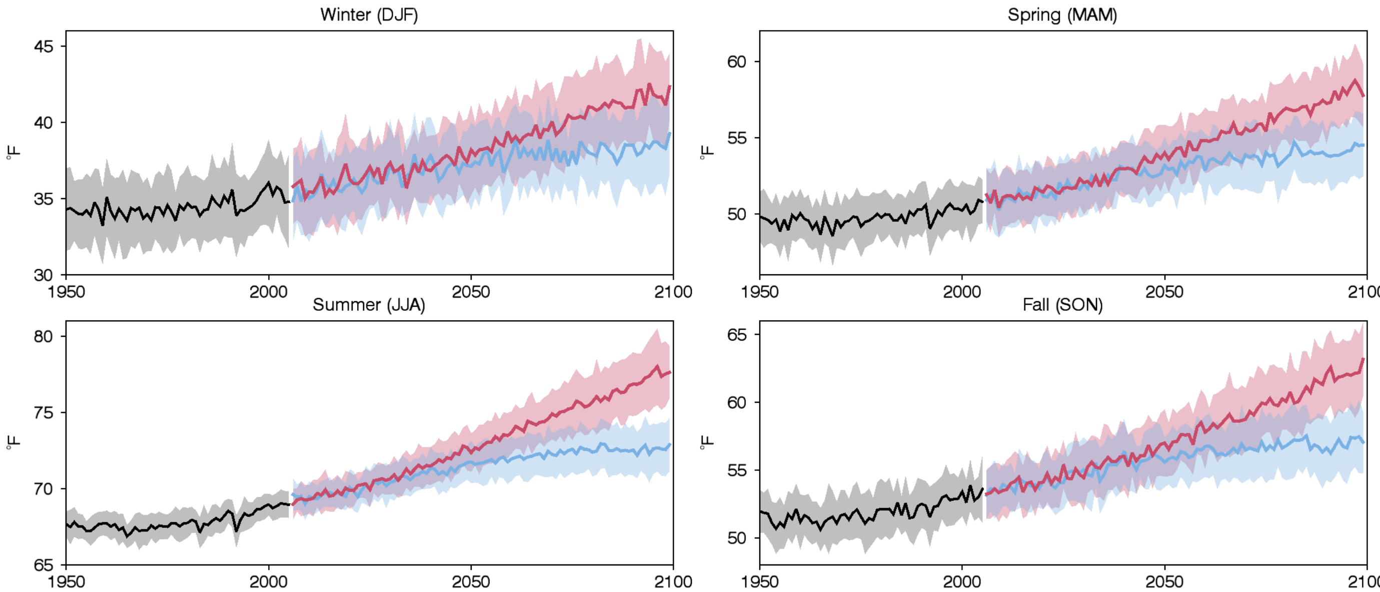


Figure 3: Seasonal average time series of minimum 2-m air temperature for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

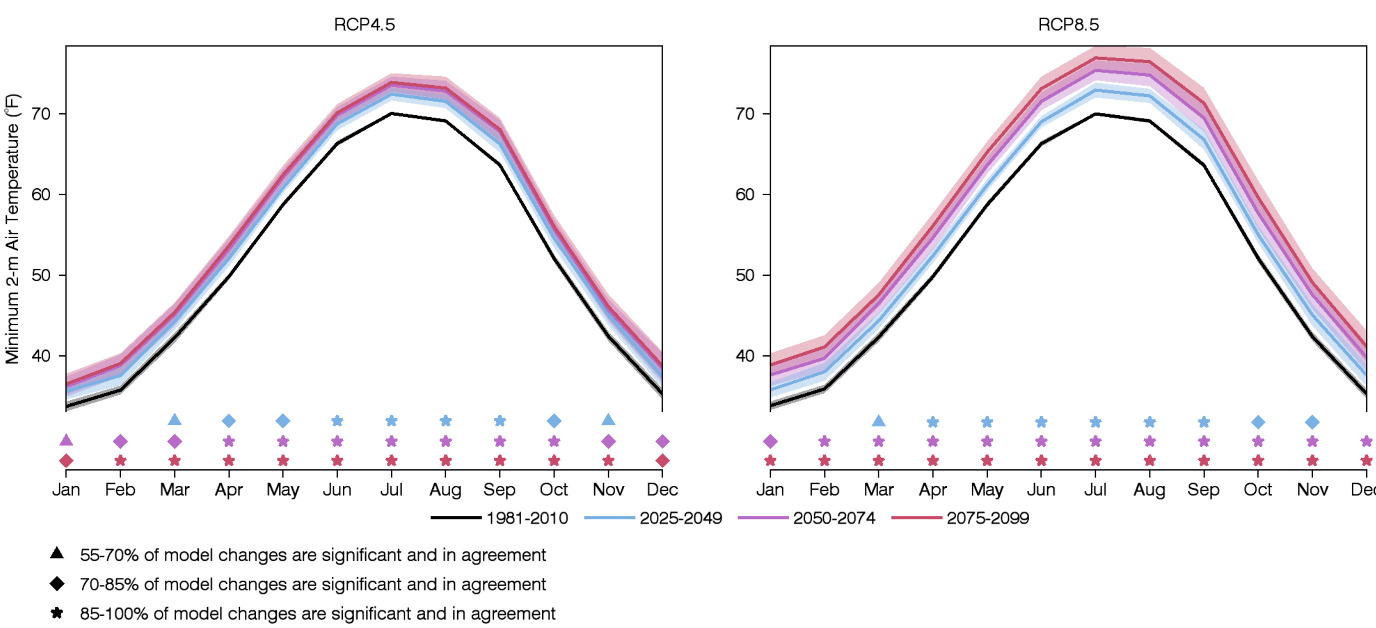


Figure 4: Monthly averages of minimum 2-m air temperature for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

3 Precipitation

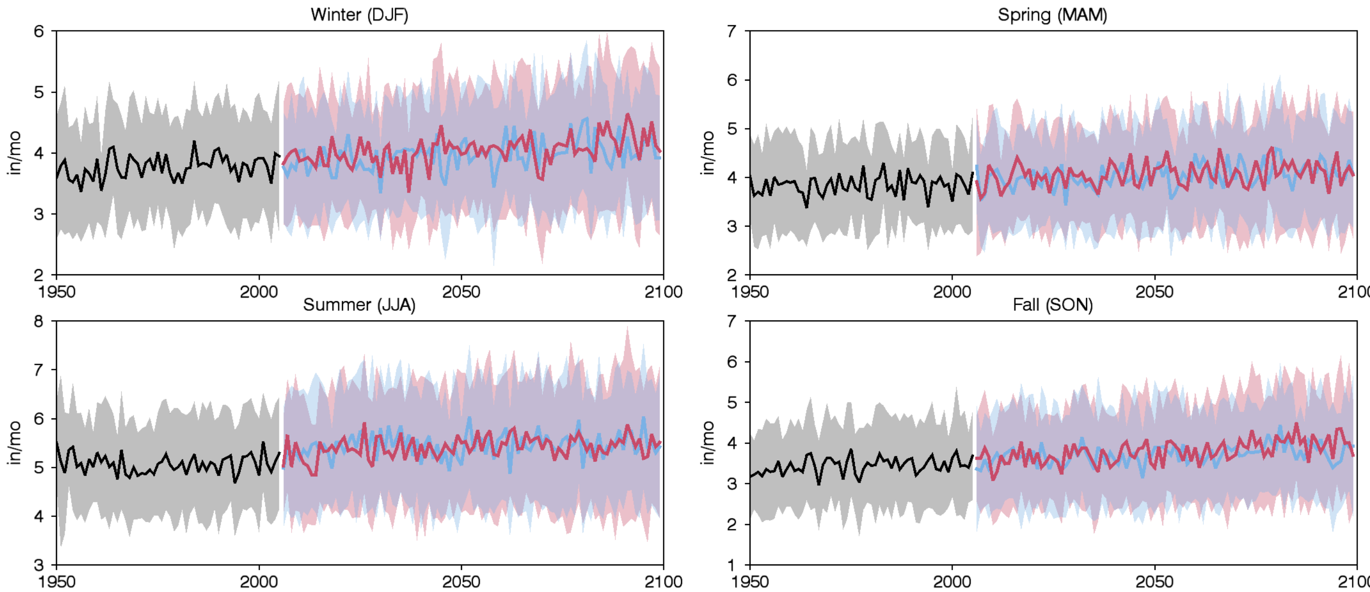


Figure 5: Seasonal average time series of precipitation for historical (black), RCP4.5 (blue) and RCP8.5 (red). The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

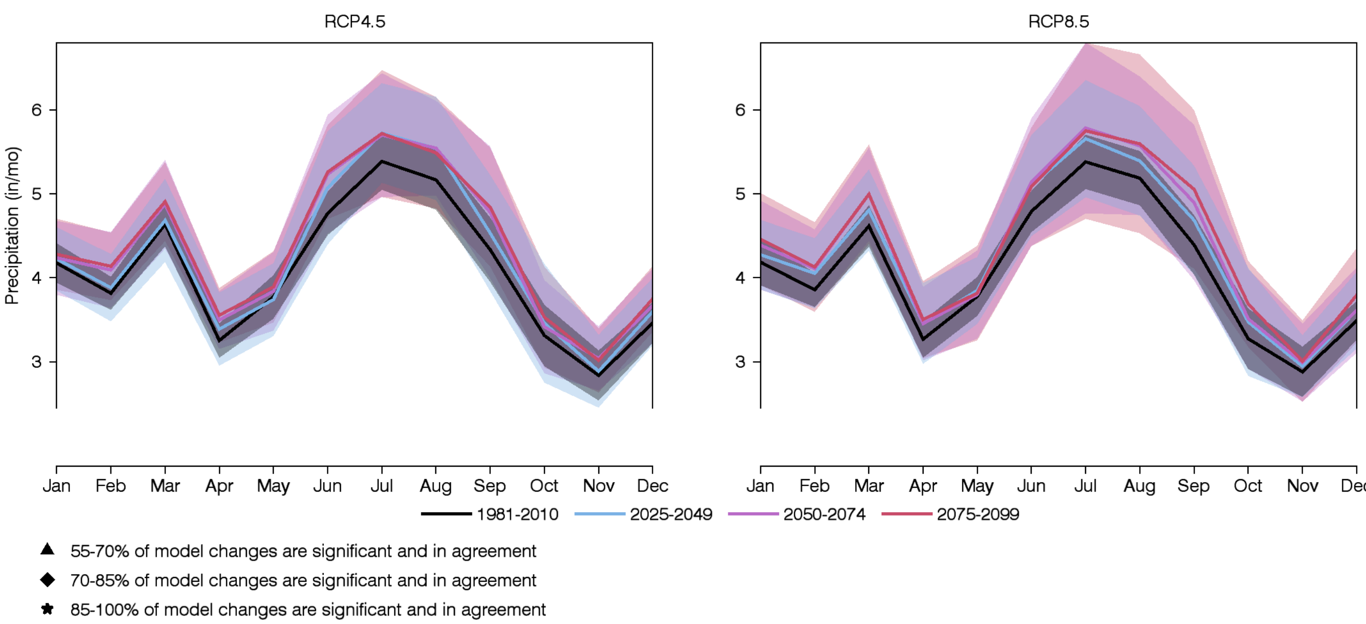
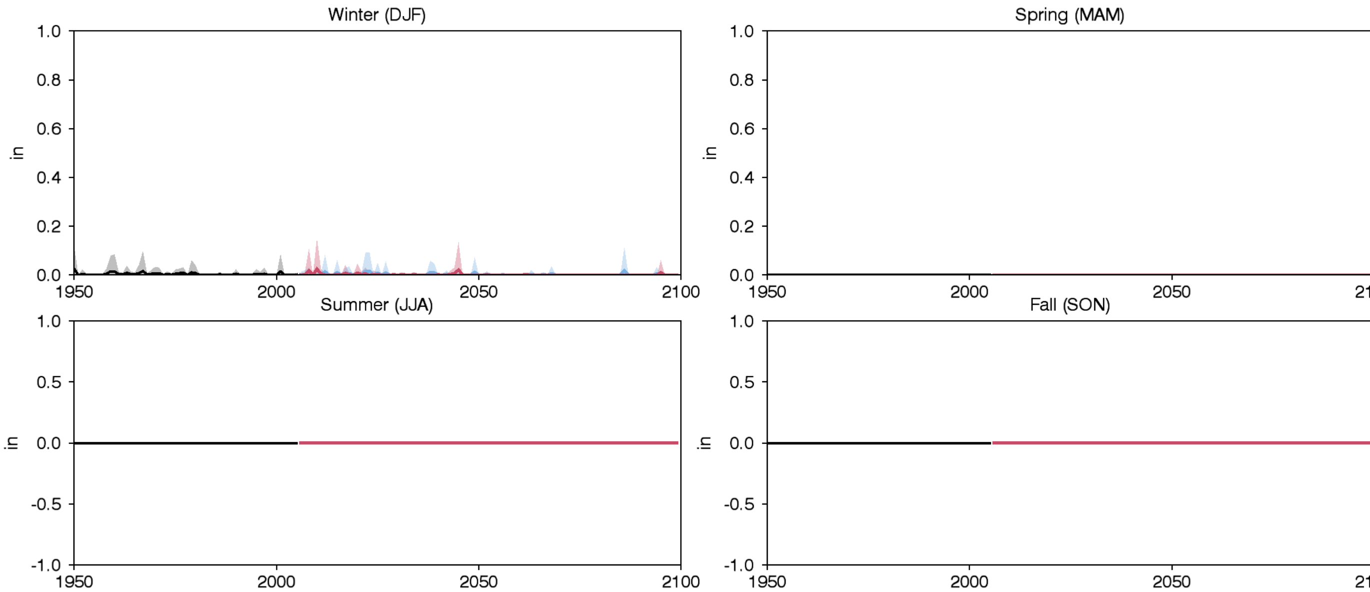


Figure 6: Monthly averages of precipitation for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes. Triangle, diamond and square symbols indicate the percent of models that simulate future minus present changes that are of the same sign and significant. A two-sided Students t-test is used to establish significance ($\rho \leq 0.05$).

4 Snow Water Equivalent



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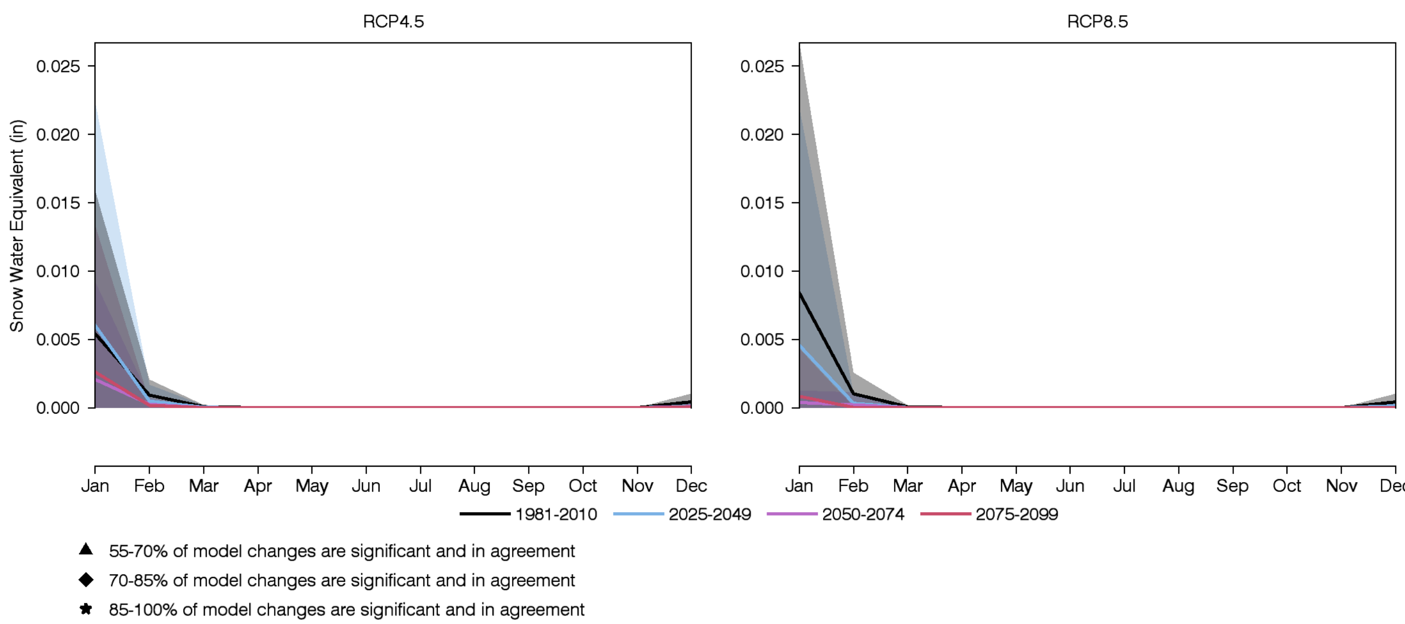

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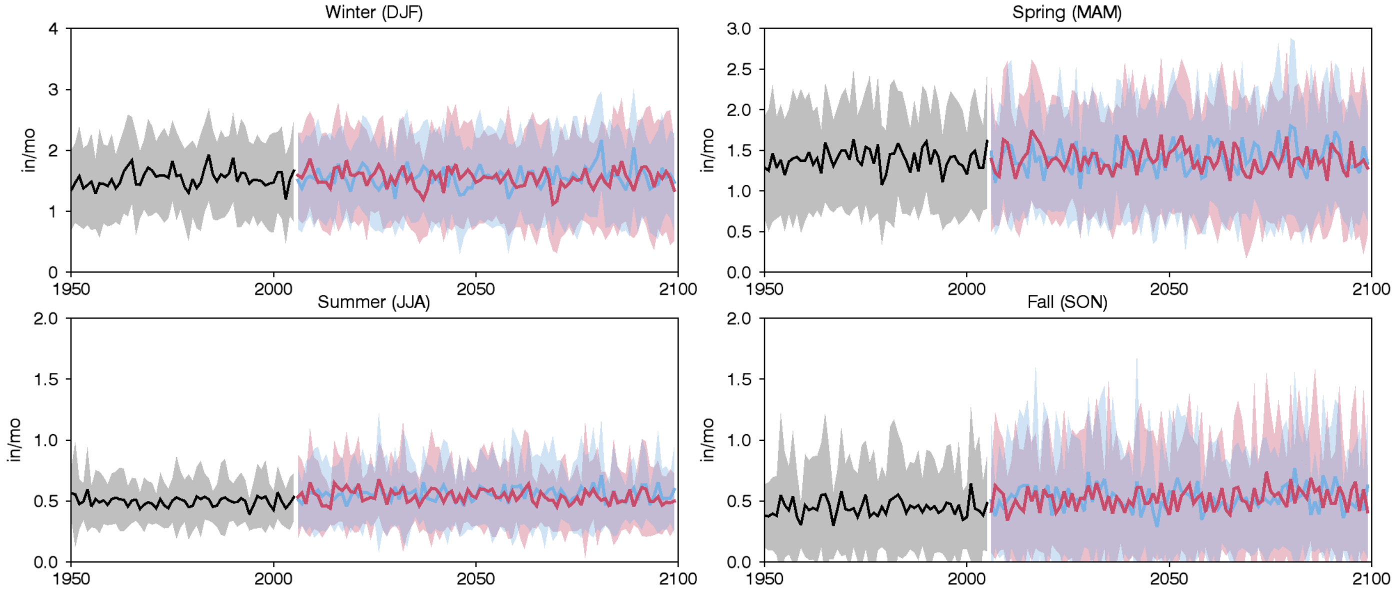
5 Runoff



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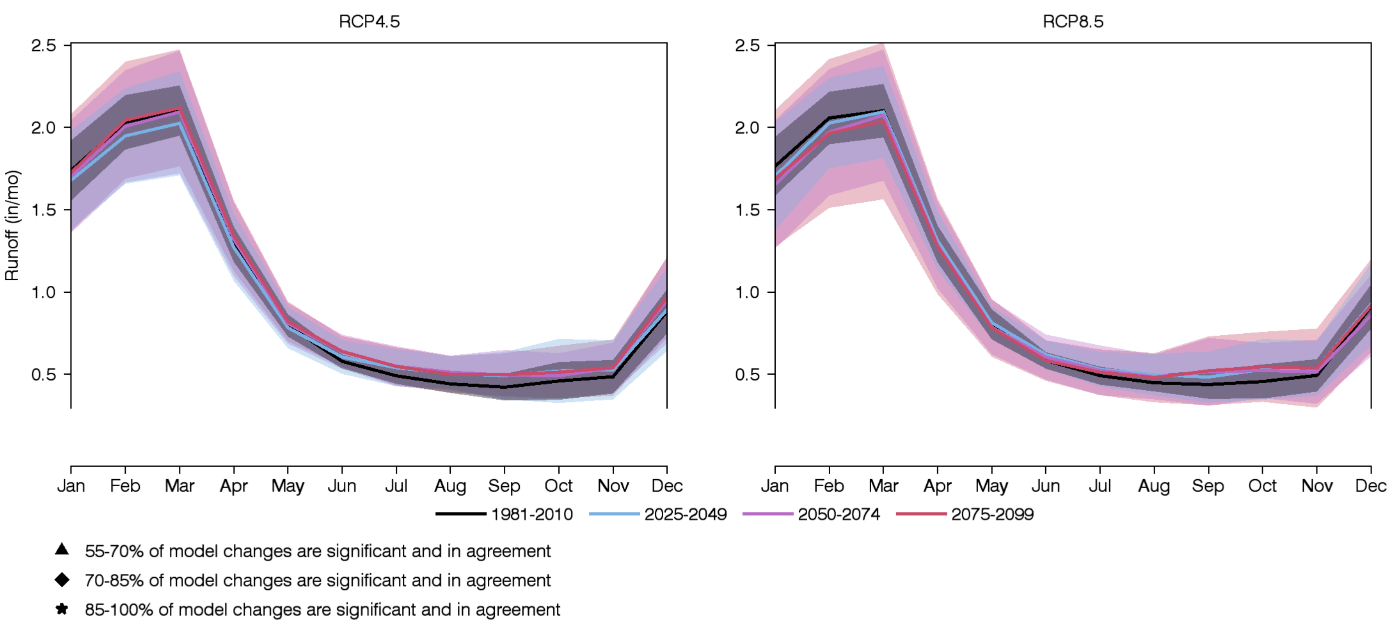

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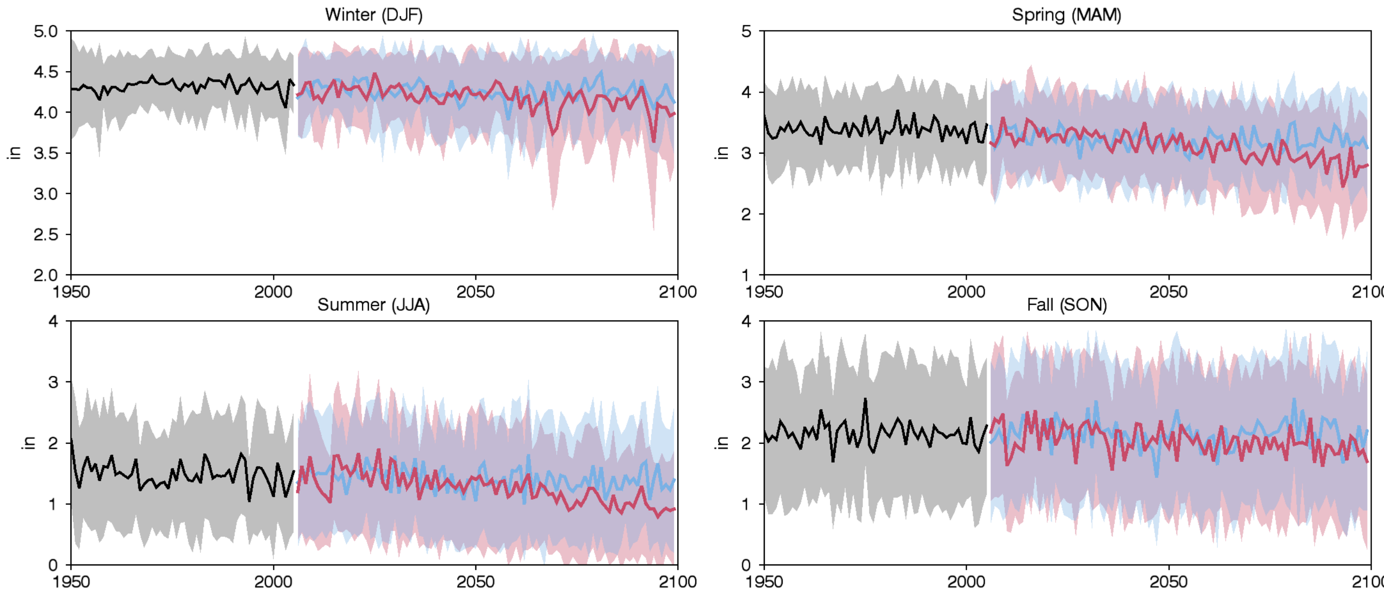

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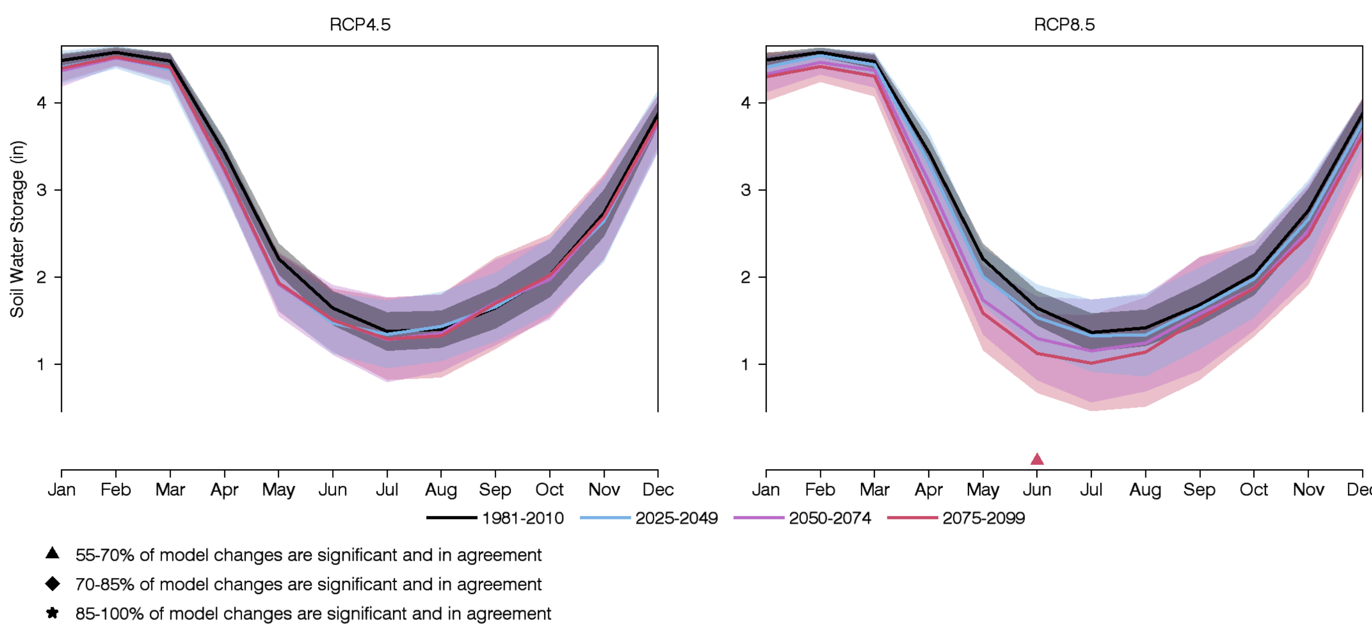

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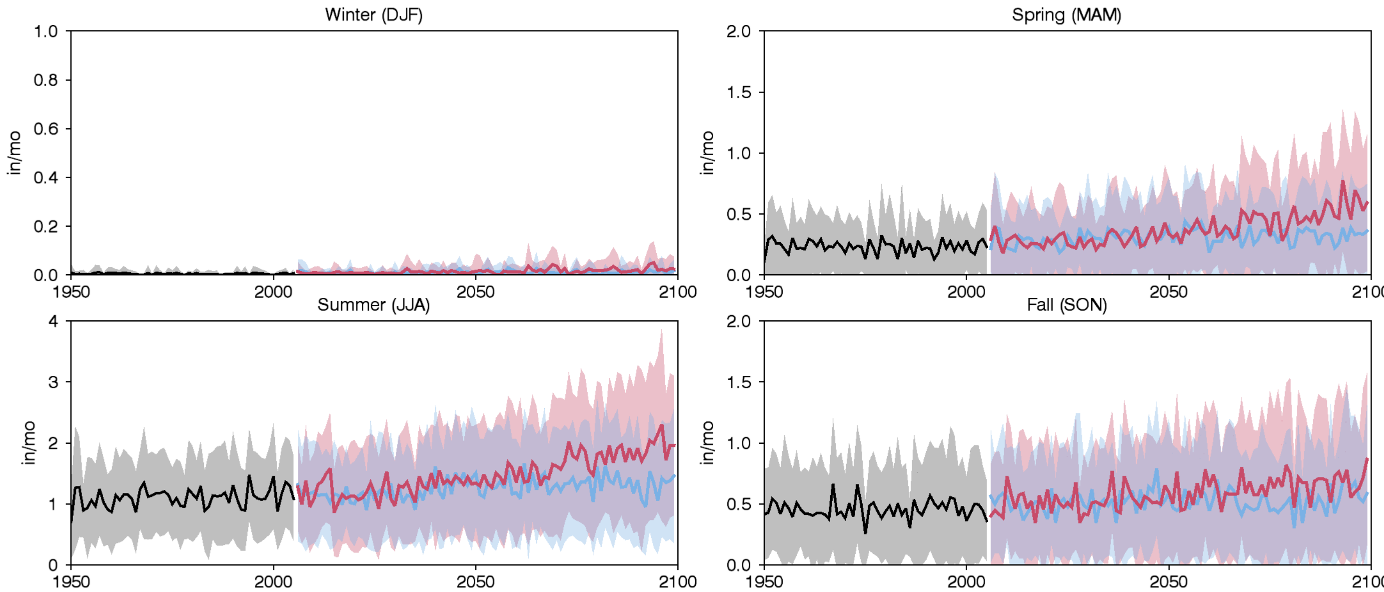
7 Evaporative Deficit



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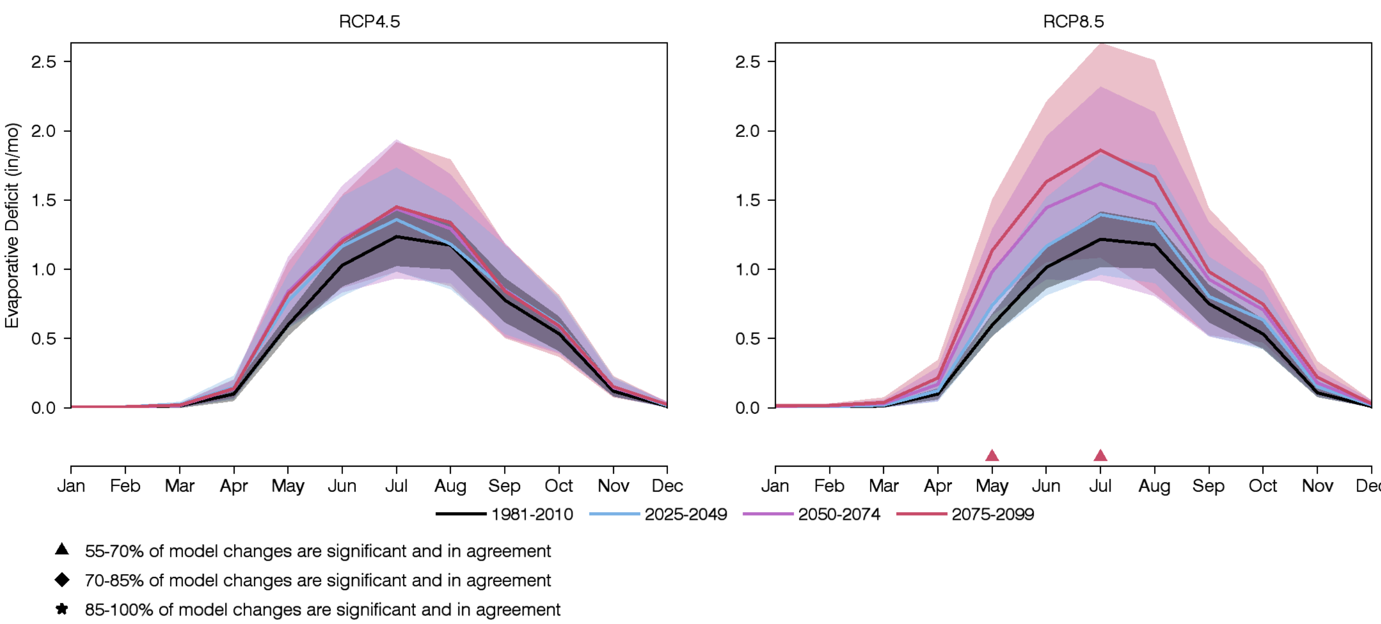

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GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M	GISS-E2-R	HadGEM2-AO	HadGEM2-CC
HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5
MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MPI-ESM-MR	MRI-CGCM3	NorESM1-M

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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 (NCNHP 2016a; NCNHP 2016b), the species consists of 113 populations distributed across 12 counties in North Carolina and South Carolina. Recent genetic research 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 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.

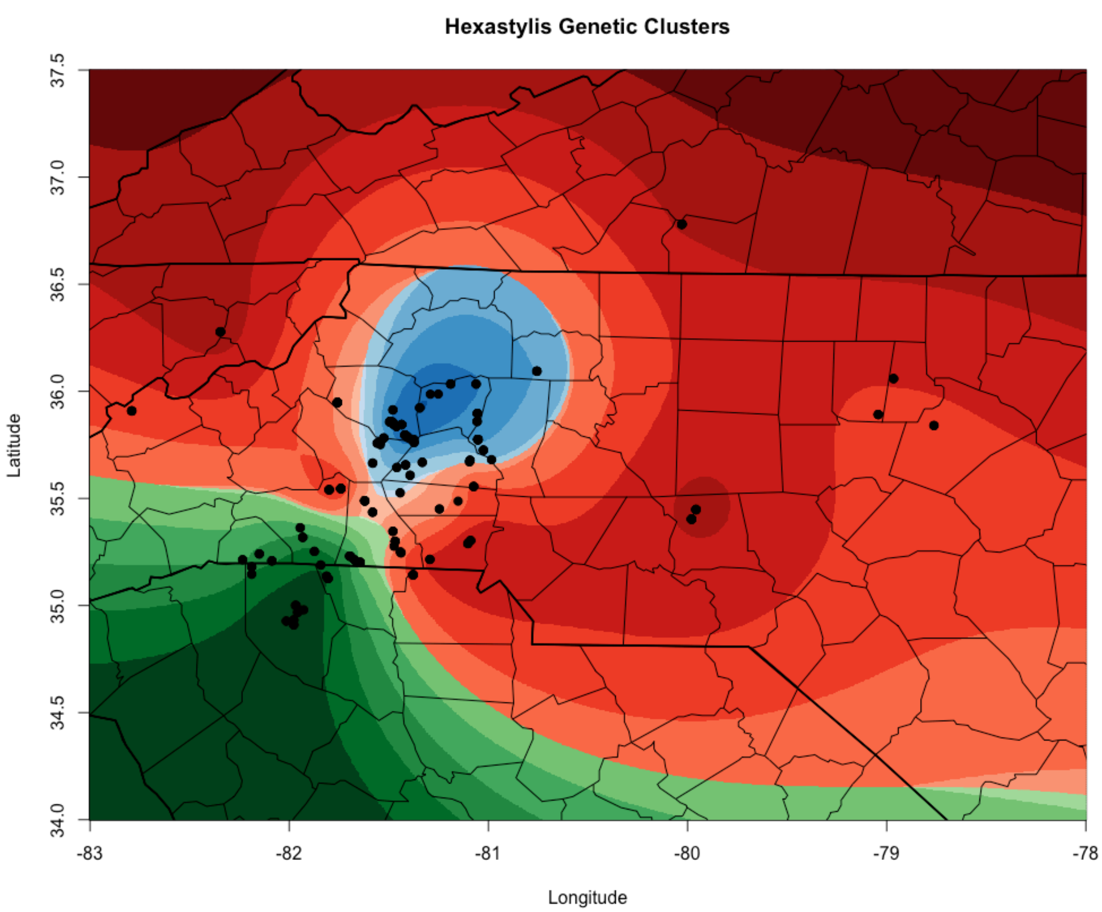

Figure 1-Recent genetic analyses detailing clustering of the genus Hexastylis. Green areas represent "true" *H. naniflora*; Blue represents a possible new species; Red represents other species in the genus (*H. minor, H. heterophylla*, etc.).

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 of years since the species was last observed at a given location (1964-2017), so although recent reports suggest the species consists of 113 populations, some of that data is fairly outdated. For the purposes of this SSA, we only used EO that were observed within the last 10 years (2007-2017). Based on that criteria, there are currently 68 populations distributed across the range of dwarf-flowered heartleaf, although this may be an underestimate as discussed in more detail in the habitat modelling section later.

To determine overall resilience for populations, we used EO viability ranks and expert opinion to bin population size classes into corresponding resilience categories. EO viability ranks for the species include excellent, good, fair, poor, extant, historical, and failed to find. The primary factor in determining these ranks is EO size (as quantified by number of clumps). Condition of habitat (vegetation community and structure) and landscape context (extent of suitable habitat and physical factors) are also incorporated secondarily. Appendix 1 shows the NCNHP EO rank specifications for dwarf-flowered heartleaf. The EO rank specifications suggest good-excellent viability for populations consisting of at least 500 individuals, given there is sufficient high quality habitat; fair viability for populations consisting of 100-500 individuals, depending on habitat conditions; poor viability for populations consisting of less than 100 individuals. Recent

reports (NCNHP 2016a; NCNHP 2016b) focus monitoring studies on populations with greater than 1,000 individuals, populations that are assumed to be very viable. Because we do not have habitat level information for every population we assessed, we synthesized all of the 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, and moderate-high probability of extirpation for 20-30 years at or above the current population size.

Occupancy and Abundance

There are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years (Table 1), and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low). Table 2 shows the contribution of each resilience category as follows: 40% (very high); 7% (high); 30% (moderate); 22% (low). When looking at cumulative percentages of resilience, it is interesting to note that 78% of all of the populations are classified as moderate to very high resilience (Table 2).

Table 1--Current populations of dwarf-leafed heartflower and associated resilience across the species range.

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

Cowpens NBF - Site 1	South Carolina	Cherokee	2016	>1000	very High
Cliffside Steam Station	North Carolina	Clev/Ruth	2016	>1000	very high
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	>1000	very high
Broad River: Brushy Creek	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Kings Mountain Res	North Carolina	Cleveland	2016	>1000	very high
Buffalo Creek: Tributaries N and S of SR 2047	North Carolina	Cleveland	2012	>1000	very high
Rhyne Conservation Preserve	North Carolina	Lincoln	2016	>1000	very high
Mill Creek Forest and Seep	North Carolina	Polk	2016	>1000	very high
New Hope Springhead Swamp	North Carolina	Polk	2016	>1000	very high
Big Horse Creek Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Broad River: Floyds Creek	North Carolina	Rutherford	2016	>1000	very high
Davenport Road/Mountain View Rare Plant Site	North Carolina	Rutherford	2016	>1000	very high
Facebook Site	North Carolina	Rutherford	2016	>1000	very high
Floyds Creek Tributray Rare Plant Site	North Carolina	Rutherford	2012	>1000	very high
New Bethel Rare Plant Site	North Carolina	Rutherford	2015	>1000	very high
Richardson Creek trib above Toms Lake	North Carolina	Rutherford	2016	>1000	very high
DNR Peters Creek Heritage Preserve	South Carolina	Spartanburg	2016	>1000	very High
Taylor Blalock Res	South Carolina	Spartanburg	2016	>1000	very High
Little Gunpowder Creek Rare Plant Site 1	North Carolina	Caldwell	2015	500-1000	high
Little Gunpowder Creek Rare Plant Site 2	North Carolina	Caldwell	2015	500-1000	high
Northern Catawba County	North Carolina	Catawba	2017	500-1000	high
Rock Barn Solar Farm	North Carolina	Catawba	2010-2011	500-1000	high
Buffalo Creek Rare Plant Site	North Carolina	Cleveland	2012	500-1000	high
Third Creek Rare Plant Site	North Carolina	Alexander	2010	100-500	moderate
Hickory Area	North Carolina	Burk/Cata/Cald	2016	100-500	moderate
Burke County - Drowning Creek UT	North Carolina	Burke	2017	100-500	moderate
Simms Hill/Little River Uplands	North Carolina	Burke	2015	100-500	moderate
Smith Cliff/Henry Fork River	North Carolina	Burke	2015	100-500	moderate
NCDOT non-TIP Div 12 road const at SR 1115 South Fork Catawba River Jacobs Fork and Camp Creek	North Carolina	Catawba	2016	100-500	moderate
NCDOT TIP R-2824	North Carolina	Catawba	2015	100-500	moderate
South Fork Catawba River, Henry Fork	North Carolina	Catawba	2007	100-500	moderate
Broad River/Sandy Run NA	North Carolina	Cleveland	2012	100-500	moderate
Brushy Creek Headwaters	North Carolina	Cleveland	2014	100-500	moderate
First Broad River: Crooked Run Creek	North Carolina	Cleveland	2010	100-500	moderate
No Business Creek, Boyd Tract	North Carolina	Cleveland	2007	100-500	moderate
West Shelby Mesic Slope	North Carolina	Cleveland	2016	100-500	moderate
UT of Kings Mountain Res	North Carolina	Gaston	2012	100-500	moderate
Buffalo Shoals Creek	North Carolina	Iredell	2014	100-500	moderate
Cat Square Heartleaf Forest	North Carolina	Lincoln	2012	100-500	moderate
Collinsville (Hughes) Creek Slopes	North Carolina	Polk	2016	100-500	moderate
Fox Knoll Farm	North Carolina	Polk	2016	100-500	moderate
Forest City: Adj to Isothermal CC	North Carolina	Rutherford	2010	100-500	moderate
Jonas Road Rare Plant Site	North Carolina	Rutherford	2014	100-500	moderate
NCDOT TIP R-3603A	North Carolina	Alexander	2017	<100	low
South Mountains Pleasant Grove Uplands	North Carolina	Burke	2016	<100	low

Gunpowder Creek	North Carolina	Caldwell	2012	<100	low
Killian Crossroads	North Carolina	Catawba	2010	<100	low
Pott Creek	North Carolina	Catawba	2012	<100	low
Beaverdam Crk at First Broad River	North Carolina	Cleveland	2011	<100	low
Buffalo Creek: Potts Creek	North Carolina	Cleveland	2012	<100	low
Buffalo Creek: Ravine	North Carolina	Cleveland	2007	<100	low
Hickory Creek - UT (Shelby High School)	North Carolina	Cleveland	2016	<100	low
Boulder Creek Subdivision - Jordan Road	South Carolina	Greenville	2016	<100	low
Gateway Elementary School	South Carolina	Greenville	2017	<100	low
Fanjoy Road Site	North Carolina	Iredell	2015	<100	low
Levan Family Farm	North Carolina	Iredell	2013	<100	low
Lincoln County, SR-1314	North Carolina	Lincoln	2014	<100	low
Northeast Lincolnton: UT Walker Branch	North Carolina	Lincoln	2009	<100	low

Table 2--Population resilience categories by county for dwarf-flowered heartleaf.

County	**Very High**	**High**	**Moderate**	**Low**	**Totals**
Alexander	1		1	1	3
Burk/Cata/Cald			1		1
Burke	2		3	1	6
Caldwell	2	2		1	5
Catawba	4	2	3	2	11
Cherokee	1				1
Clev/Ruth	1				1
Cleveland	4	1	5	4	14
Gaston			1		1
Greenville				2	2
Iredell			1	2	3
Lincoln	1		1	2	4
Polk	2		2		4
Rutherford	7		2		9
Spartanburg	2				2
Totals	**27**	**5**	**20**	**15**	**67**
% of total	*40*	*7*	*30*	*22*	*100*
Cumulative %	*40*	*48*	*78*	*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 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 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: NCNHP).

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	Rhyne 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
	NCNHP	Broad River: Henson's Creek, Brice, & Sandy Mush Outcrop (EO 099)	106,940	83.39
	NCNHP	Broad River: Cleghorn Creek, US 221 (EO 176)	6,750	7.24
	NCNHP	Cowpens National Battlefield (SC EO 016, 017, 018)	2,823	6.05
	NCNHP	Peters Creek Preserve (SC EO 011)	3,306	8.98
	NCNHP	Blalock Reservoir (SC EO 007, 031)	3,505	7.59
Decreasing	NCNHP	Second Broad River (Forest City Industrial Complex) (EO 154)	2,576	4.74
	NCNHP	South Fork Catawba River: Jacob Fork, Camp Creek (EO 158)	123	0.09

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

A previous habitat suitability study attempted to quantify the habitat requirements for dwarf-flowered heartleaf. A model was created to predict habitat suitability, and based on the model results, the strongest habitat correlations were slope, aspect, soil type, elevation, and land use (Wagner 2015). With this model in mind, 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 2.

Source Data and Model Variables

Fifty three, 10-digit hydrologic units (HUC) comprise the analysis extent. In North Carolina, it includes all 10-digit HUC that fall within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*. In South Carolina, we also included all 10-digit HUC that fell within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*, 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. These data were in polygon format and digitized at a scale that accurately identified the boundaries of the individual population areas. 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 in the last 10 years (2007). 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.

Model Development

We used Maxent software (version 3.4.1) for species habitat modeling (Philips 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, SSURGO drainage class, SSURGO hydrologic group, aspect 9-class, aspect 5-class, slope, and maximum annual temperature.

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 2 shows the model output. The minimum cutoff value (to determine if an area is considered potential habitat for a species) of 0.406 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 predictions to focus on the typical habitat conditions for this species. The total area ranked greater than 0.406 in the Maxent model was just 6.39% of the total analysis area (Table 4).

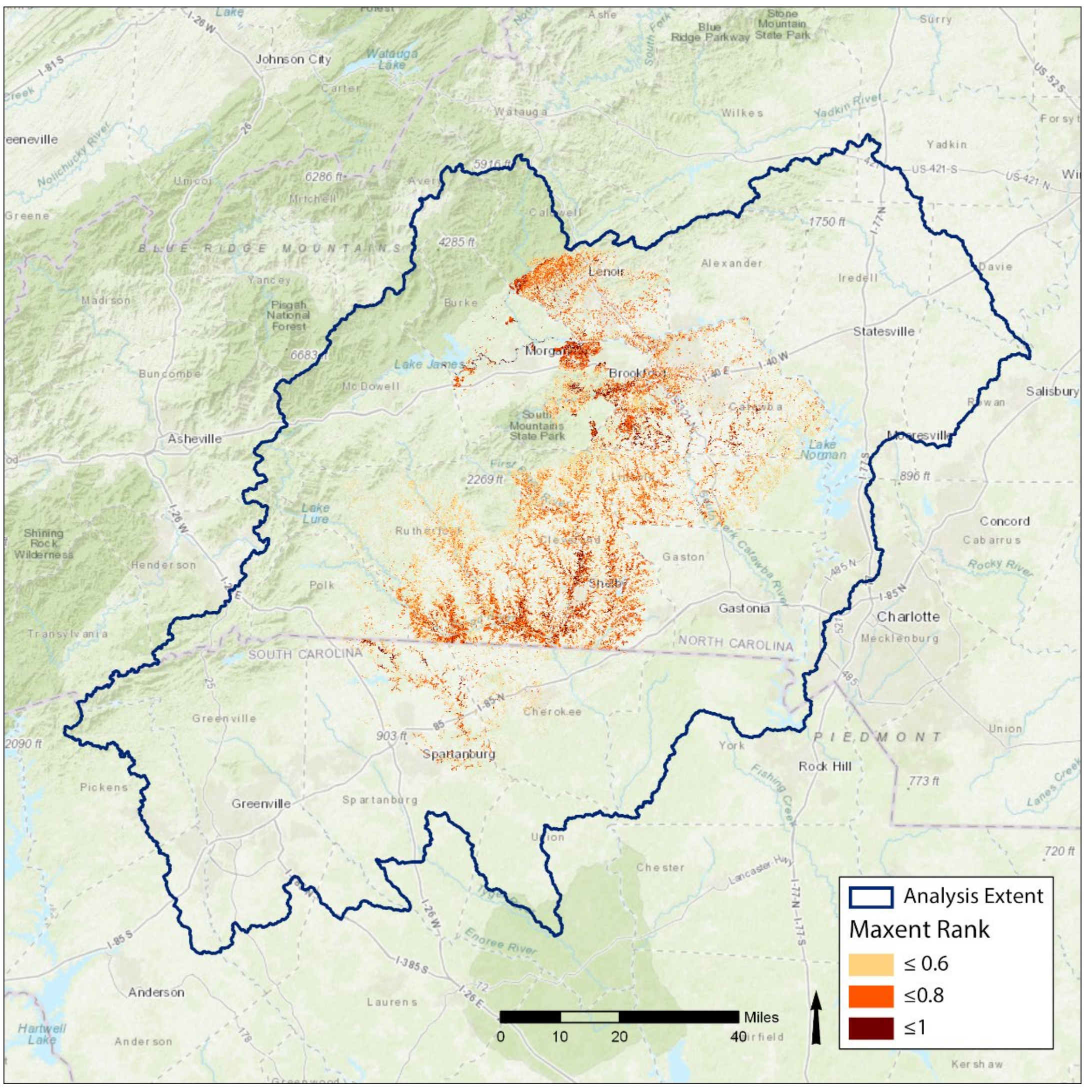

Figure 2-Maxent model output map

Table 4-Area estimates of the Maxent model

Maxent Score	Acres	Square Miles	Percent of Total
0.406 and greater	321,262.37	501.97	6.39%
0.6 and greater	146,712.65	229.24	2.92%
0.8 and greater	22,677.96	35.43	0.45%

The average area-under-curve (AUC) score for the replicate Maxent model is 0.849. The AUC is calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1 and may be interpreted as a single test statistic that assesses model performance, indicating the ability of the model to correctly classify the occurrence data used. The model performed well in its predictions, with a mean AUC of 0.849 (AUC value of 0.5 is no better than random; AUC<0.5 is worse than random; AUC>0.5 is greater predictive power than random; Baldwin 2009).

The Maxent output supplies estimates of the relative contributions of the environmental variables to the Maxent model (Table 5). SSURGO mukey is the top contributing variable. One hundred and thirty-five individual soil types are present within the polygon boundaries of the *Hexastylis naniflora* element occurrences. Many of these individual soil types are part of soil complexes and are separated by things such as percent slope, erosion, how stony/rocky, and amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25 to 60 percent slopes, very stony (12.9% of total). However, collectively the Meadowfield soils only comprised 13.5% of all soils). The individual Pacolet soil types were very common and collectively comprise 36% of all soil types present. Woolwine soils were also collectively common, comprising 10% of all soils present.

The minimum annual average temperature range in the analysis extent is 39 – 51 degrees Fahrenheit. The majority of the *Hexastylis naniflora* element occurrences (92%) 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 (81%) are found in the 47 – 49 inches per year range.

Piedmont forested landcover habitats dominate the land area of the element occurrences. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier (52%), Southern Piedmont Mesic Forest (10%), Southern Piedmont Small Floodplain and Riparian Forest (3.6%), and Southern Piedmont Dry Oak-Pine Forest – Loblolly Pine Modifier (2.3%) collectively comprise 72% of the element occurrences area. Unfortunately, non-native habitats are also present. Evergreen Plantation or Managed Pine (8%), Harvested Forest – Grass/Forb Regeneration (7%), Developed, Open Space (5%), Pasture/Hay (2.5%) 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 landcover classes, but each at small percentages.

The landcover majority classification scheme reduces the total number of landcover classes present in the analysis extent from 23 to 12. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landcover class (56%). 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 landcover area representation in the landcover majority layer suggests that many *Hexastylis naniflora* population areas are situated in areas impacted by disturbed landcover. This is likely due to urban encroachment and increasing fragmentation of habitats.

The landcover Hexastylis grouping reveals the amount of disturbance present in Hexastylis population areas. Landcover classes grouped as disturbed comprises 26% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, hardwood forest 11%, and riparian 3.6%. Open water, evergreen and barren landcover groupings are all at less than 1% each.

Geomorphons revealed that the majority of *Hexastylis naniflora* element occurrence areas are situated in concave landforms. Geomorphon categories hollow (15%), valley (35%), and depression (17%) collectively comprise 67% of all *Hexastylis naniflora* population areas. Flat landforms comprise 22.5% of the area and convex landforms the remaining 10.5%.

Within the analysis extent, the range of elevation present is 335 – 5,265 feet. For *Hexastylis naniflora*, the prime elevation range is from 666 – 896 feet (54% of total element occurrence area). A lesser elevation range is present from 935 – 1,165 (35% of total element occurrence area).

Table 5-Percent contribution of the environmental variables

Environmental Variable	Percent Contribution
SSURGO mukey	23.3%
Minimum Annual Temperature	20.7%
Average Annual Precipitation	14.6%
Landcover	13%
Landcover Majority	9.5%
Landcover Hexastylis Grouping	7.3%
Geomorphons	6.4%
Elevation	5.2%

We performed an Analysis of Variance test to investigate the relationship between Maxent scores and current resilience of populations (Table 6). There are significant differences in the average Maxent scores between the four resilience categories ($p = 0.01$) and the mean Maxent score increases as population resilience increases for low to very high. It appears the model gives us some predictive ability regarding habitat quality, where higher Maxent scores, on average, result in higher population resilience.

Table 6-Results of the ANOVA investigating relationships between Maxent scores and current resilience groups for dwarf-flowered heartleaf.

Groups	*Count*	*Sum*	*Average*	*Variance*
low	13	5.240363	0.403105	0.124194
moderate	20	8.851696	0.442585	0.040139
high	4	2.292114	0.573028	0.039821
very high	27	16.66603	0.61726	0.020717

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.563333	3	0.187778	3.870253	0.01346	2.758078
Within Groups	2.911089	60	0.048518			
Total	3.474421	63				

Current Species Representation

Representation describes the ability of a species to adapt to changing environmental conditions. We lack genetic and ecological diversity data to characterize representation for dwarf-flowered heartleaf. In the absence of species-specific genetic and ecological diversity information, we typically evaluate representation based on the extent and variability of habitat characteristics across the geographical range. However, the dwarf-flowered heartleaf has a very limited range, and after consulting with experts, we decided delineating representative units was not appropriate for this species.

Current Species Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events (such as a rare destructive natural event or episode involving many

populations). Redundancy for dwarf-flowered heartleaf is the total number and resilience of population segments and their distribution across the species range. As stated previously, there are 67 populations of dwarf-flowered heartleaf that have been observed within the last 10 years, and resilience of these populations is as follows: 27 (very high); 5 (high); 20 (moderate); 15 (low); 2 (unknown). The populations are spread across the range, although a majority occur in North Carolina. Although, there appears to be adequate redundancy within the range of dwarf-flowered heartleaf, the species range is very small, making it potentially vulnerable to catastrophic events. Thus, we classify redundancy as inherently low for the species.

INFLUENCES ON VIABILITY

Hexastylis naniflora populations occur in rapidly growing urban areas with expanding suburbs of Charlotte, NC, to the east; Hickory, NC, to the north; and Greenville and Spartanburg, SC, to the south. At the time of listing, it was determined that the species was most threatened by habitat loss due to the conversion of land to residential, commercial, and industrial use in these areas. In addition to threats associated with residential, commercial, and industrial development, other documented threats include habitat loss from land conversion to agricultural use, timber harvest, hydrological alterations from the damming of ponds, impacts from grazing cattle, ORV damage, trampling from foot traffic, invasive species, highway or road improvements, and erosion or siltation (NCNHP 2016, Robinson and Padgett 2016). Climate change may exacerbate these risk factors through changes in temperature and precipitation.

Threats were assessed for populations monitored by NCNHP during 2012-2016 (Robinson and Padgett 2016), and EOs were reviewed for other documented threats to populations. Indirect or direct threats that were observed, inferred, or suspected to have an impact on populations were recorded and assigned a ranking based on their severity, scope, and immediacy from field observations. The rank for each threat factor determines the overall value for each threat observed at each population. No significant changes in threats within populations were noted from 2012-2016. Threats observed during these years included development, incompatible forestry practices, agriculture, trampling, invasive exotic species, sedimentation, erosion, and road construction.

Below, we summarize primary threats to the viability of dwarf-flowered heartleaf. Primary influences will be carried forward in our future projections in the next section.

Human Population Change

Increasing human populations drive development. With increases in population, there will be increasing conversion of open space to more impervious cover, with a subsequent increase in roads and other associated infrastructure. Increases in roads and impervious cover have the potential to lead to habitat loss and/or fragmentation, a primary risk factor for dwarf-flowered heartleaf. Tables 1-2 and Figures 1-2 show the estimated human population increases for North

Carolina and South Carolina counties within the range of the species. The most populous counties include Greenville and Spartanburg in South Carolina, and Catawba, Gaston and Iredell counties in North Carolina.

Table 1-Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

County	2018	2023	2028	2033	2037
Alexander	38609	39,244	39,686	39992	40169
Burke	90865	93,124	95,382	97644	99452
Caldwell	83919	86,723	88,689	91126	92870
Catawba	157424	159,799	162,175	164549	166447
Cleveland	98862	99,685	100,004	100128	100170
Gaston	221112	227,667	237,344	245276	252388
Iredell	179740	195,623	211,501	227383	240088
Lincoln	84494	91,034	96,865	103069	107858
Polk	21273	21,823	22,288	22681	22955
Rutherford	67880	68,154	68,283	68341	68368

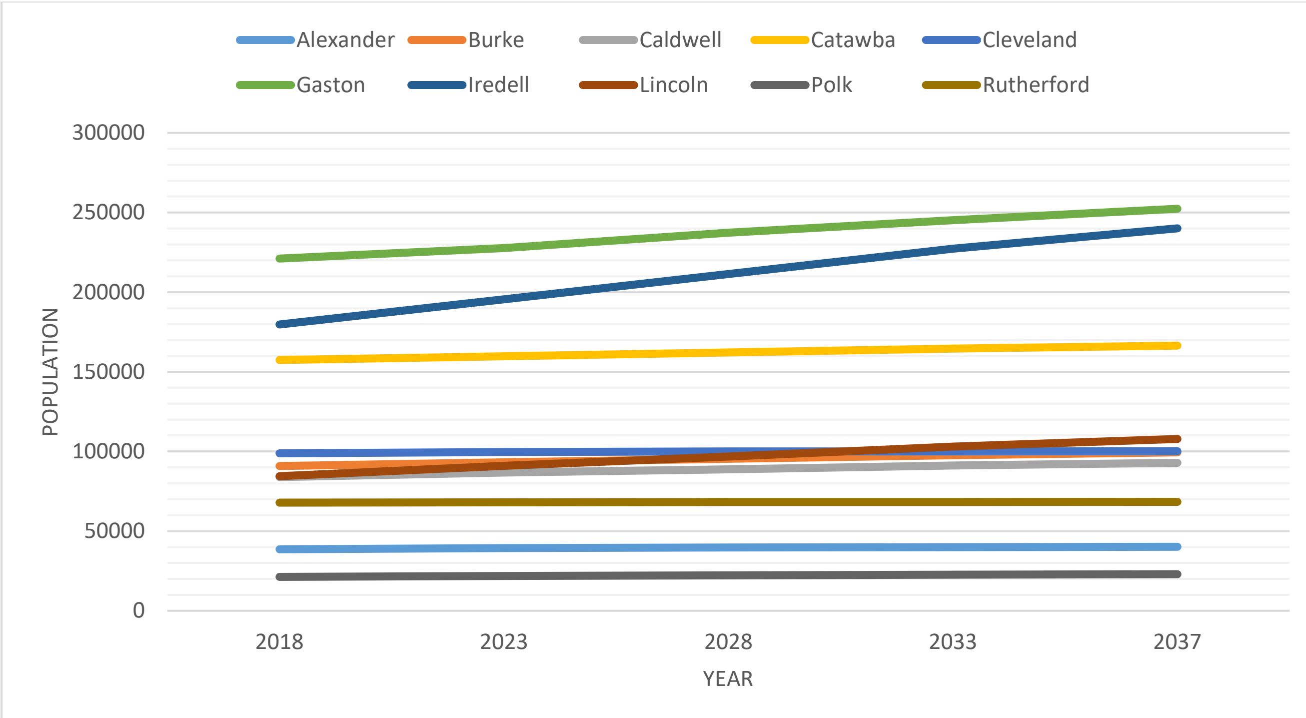

Figure 1- Human population projections for North Carolina counties within the range of dwarf-flowered heartleaf. *Source: North Carolina OSBM, Standard Population Estimates.*

Table 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
Greenville	492,890	517,740	542,290	567,010
Spartanburg	310,220	323,550	336,810	350,110

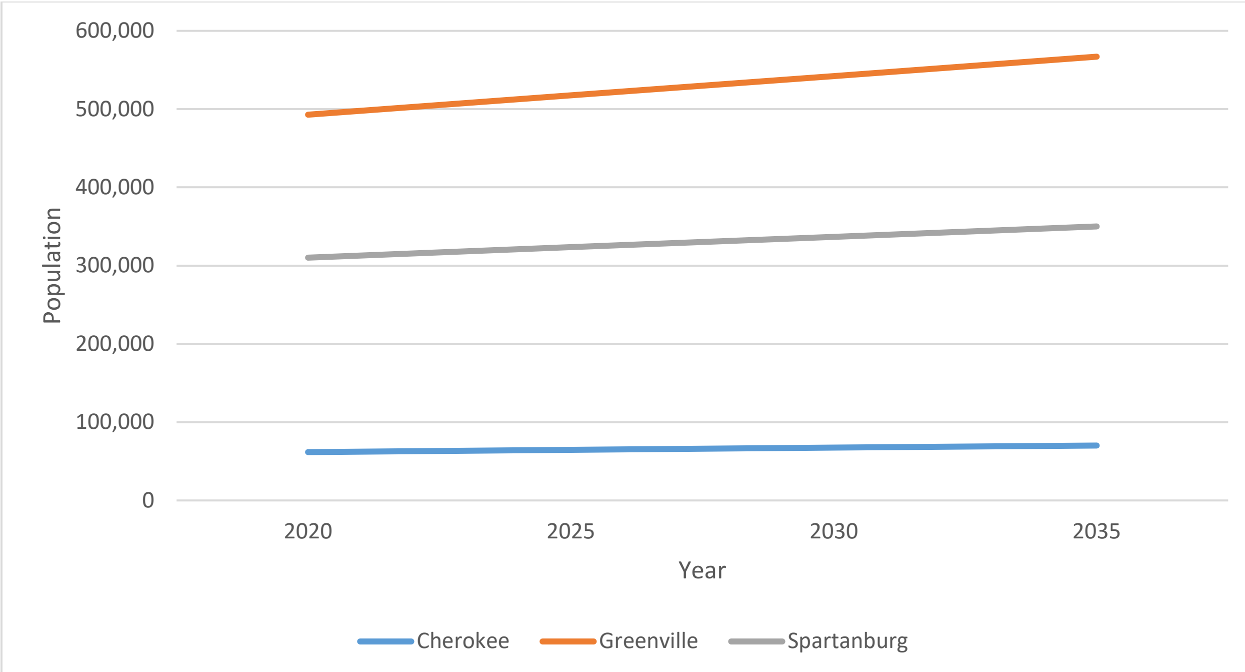

Figure 2- Human population projections for South Carolina counties within the range of dwarf-flowered heartleaf. *Source: U.S. Census Bureau, 2000 Census and 2007 Population Estimates. Population projections calculated by South Carolina Budget and Control Board, Office of Research and Statistics.*

Development

A large number of the known populations occur near expanding urban areas and are threatened by the residential, commercial, and industrial development associated with this growth. Populations occurring in more rural areas are threatened by habitat alteration or loss from land conversion to pasture or other agricultural uses, cattle grazing, intensive timber harvesting, residential construction, and construction of small ponds.

A 2011 review of existing NHP EOR data revealed that all or portions of 26 populations (24% of the total) had been directly or indirectly impacted through development projects or other causes such as trash disposal, expansion of residential lawns, cattle, or invasive exotics (NC NHP 2010; SCDNR 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

foreseeable within 42 of the 108 populations (corresponding to 39% of all known populations). Of these 42 populations, all or portions of 22 (50%) had been adversely impacted by activities requiring ESA Section 7 consultation with the USFWS. The fact that nearly 20% of all known populations had been subject to formal Section 7 consultation illustrates the threats faced by the species.

The most recurrent source of habitat destruction, and certainly the most common trigger for Section 7 consultations involving *H. naniflora* is road and bridge improvement projects. Ten of the 27 largest populations (containing more than 1,000 rosettes) have been the subject of Section 7 consultations between the USFWS and the NCDOT. Collectively, these projects have adversely impacted or are currently expected to impact some 22,135 rosettes. In most cases the Section 7 process has resulted in avoidance or minimization of adverse effects through relocation of plants and/or commitments of on-site protection to those plants remaining (post-construction) within NCDOT right-of-way (ROW).

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 consultations with the USFWS. Examples of these activities include the maintenance or expansion of hydroelectric and drinking water reservoirs, construction of an industrial development complex, and maintenance activities (in compliance with Federal Aviation Administration standards) at a regional airport. Collectively, these activities have involved the loss or relocation of several thousand rosette.

Blalock Reservoir in Spartanburg County, South Carolina was once estimated to contain the largest population of *H. naniflora*, with over 11,000 rosettes reported here in 1997 (JJ&G, 1998). This population was the subject of a section 7 consultation as a result of a proposal to raise the elevation of Blalock Reservoir, which provides water supply storage to Spartanburg County and the City of Spartanburg (USFWS, 2001). Approximately one-third of this population was directly threatened by inundation, and the Federal agency committed to the relocation of some 3,054 rosettes to remaining areas of occupied habitat around the reservoir. At the conclusion of formal section 7 consultation, the USFWS anticipated that as many as 6,619 rosettes (assuming

that all transplants survived) would be afforded protection through restrictive covenants placed on properties owned by the Spartanburg Water System (SWS) surrounding Blalock Reservoir. However, this population was last reported to contain a mere 1,400 rosettes (Newberry, 2006), and has twice since been impacted by encroachments from adjacent landowners (Newberry, 2009; Schneider, 2006, and JJ&G, 2006). Some of these apparent declines could be partially an artifact of incomplete survey effort, in that the exhaustive surveys which led to the 1997 estimate (of 11,000 rosettes) have never been repeated. However, it seems unlikely that plants occurring on privately owned shoreline not subject to restrictive covenants would be any more stable than those occurring on properties specifically protected and managed for the species (by SWS).

Invasive Species

Several of the known populations of dwarf-flowered heartleaf occur on steep ravine slopes which also support stands of mixed hardwoods with an understory of mountain laurel (*Kalmia latifolia*) or *Rhododendron spp*. These stands are often very dense and reduce the amount of light reaching the dwarf-flowered heartleaf plants growing below. Under these conditions the plants often show reduced vigor and reduced flower and fruit production. Careful, selective logging or natural tree fall and limited understory removal would open up these populations to more light. Additional light, if not accompanied by increased siltation from the intensive soil disturbances associated with forest clear-cutting, probably would benefit these populations (Gaddy 1981).

Invasive exotic plant species are rampantly spreading throughout riparian corridors and ravines across the range of this species. Invasive exotics such as English Ivy (*Hedera helix*), Chinese privet (*Ligustrum* spp.), Japanese honeysuckle (*Lonicera japonica*) and Japanese Nepal grass (*Microstegium vimineum*) are known to threaten several populations; however, the scope and magnitude of this threat has not been comprehensively assessed. This threat requires active management in order to be successfully abated. At present, the majority of protected populations are secured against habitat conversion, but lack designated managers with the technical expertise and available resources (funding and personnel) to address this threat.

Climate Change

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

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

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

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 (NCILT 2012, p.27; IPCC 2013, p.7):

- More frequent drought
- More extreme heat (resulting in increases in air and water temperatures, Figure 5-3)

- Increased heavy precipitation events (e.g., flooding)
- More intense storms (e.g., frequency of major hurricanes increases)
- Rising sea level and accompanying storm surge

In recent years, the Southeast has experienced moderate to severe droughts that many observers have implicated in population declines and poor transplant survivorship (NC NHP, 2010). A wildfire, presumably brought on or at least exacerbated by drought conditions, burned portions of one of the largest known populations in 2009 (Foothills Landfill in Caldwell County; Golder and Associates, 2009). Accelerated climate change is expected to increase the frequency and extent of drought conditions across the southeast (Karl, et al. 2009). The extent to which these climate changes will significantly affect populations of dwarf-flowered heartleaf is currently unknown.

Appendices 3a and 3b gives summary reports on historical and future predicted climate parameters from the USGS National Climate Change Viewer for both North Carolina and South Carolina. As discussed above, the trend for these States is as it is for the Southeast in general: more frequent drought, more extreme heat, and increased precipitation events. If these predictions hold true, dwarf-flowered heartleaf habitat would likely be impacted through increased evaporative rates and decreased soil moisture (Appendices 3a and 3b), increased potential for catastrophic wildfire events, as well as potential disruption of stream bank morphology through increased flooding events.