Species Status Assessment Report for the *Scutellaria ocmulgee* (Ocmulgee skullcap)

Version 1.2

Photo By: Ed McDowell

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South Atlantic-Gulf Region
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SUMMARY OF VERSION UPDATES

The changes from version 0.1 (December 2019) to version 0.2 (March 2020) are minor and do not change the assessment of risk. The following changes were made:

1. Added Executive Summary
2. Added Acknowledgements
3. Corrected grammatical errors
4. Corrected formatting inconsistencies
5. Added missing page number from in-text citations
6. Clarified that modifications to Army Corps of Engineers' Water Control Manuals were not considered in future conditions scenarios

The changes from version 1.1 (March 2020) to version 1.2 (December 2020) are minor and do not change the assessment of risk. The following changes were made:

1. Corrected typographical errors
2. Removed disclaimer
3. Added climate change projections from the National Climate Change Viewer
4. Corrected population delineations and revised maps, tables and text for consistency
5. Reorganized discussion on redundancy and resiliency

EXECUTIVE SUMMARY

Background

Ocmulgee skullcap (*Scutellaria ocmulgee*) is in the Lamiaceae (mint) family and is restricted to the calcium rich slopes along the Ocmulgee and Savannah river watersheds. In these isolated areas, the forest structure is comprised of a mixed-hardwood species of trees with a partially open canopy to allow the plants to reach maturity and produce viable seed. Ocmulgee skullcap requires little to no competition for needed resources (e.g., sunlight, calcium, pollinator presence, stable soil conditions, etc.) to reach maturity and produce seed. Other factors influencing the species include herbivory from white-tailed deer, habitat loss and fragmentation due to urbanization and forest conversion, competition from nonnative invasive species, and the effects of a changing climate.

Methodology

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

We delineated populations of the Ocmulgee skullcap using occurrence data obtained from peer-reviewed articles, unpublished survey reports, and survey records (1961 to present) contained in agency and partner databases (i.e., GA and SC Natural Heritage databases). We used NatureServe's Habitat-based Plant Element Occurrence Delineation Guidance and expert recommendations when delineating populations.

We made qualitative assessments of the current condition (viability) of each population through evaluations of components describing the species' physical environment (Habitat Metric) or its population characteristic (Demographic Metric). Habitat elements included condition of the native herbaceous ground cover (i.e., presence of nonnative invasive plant species, presence of deer herbivory signs, and change in habitat condition). Demographic elements included the abundance of individuals within a population, the number and distribution of occurrences within a population, and the change in the number of occurrences within a population (increasing, stable, or decreasing).

We further defined how each of these components might vary in terms of condition. These metrics were selected because the supporting data were consistent across the range of the species and at a resolution suitable for assessing the species at the population level. The model output was a resiliency condition class score for each Ocmulgee skullcap population that was then used to assess the species' current condition across its range relative to resiliency, redundancy, and representation.

We assessed the species' condition and potential viability under three future scenarios. We chose to model these scenarios at 2040 and 2060 (20 and 40 years in the future) because we have data to reasonably predict potential habitat conditions and effects to species within this

timeframe and the time steps allow 4–8 generations of Ocmulgee skullcap to respond to influences on viability. We incorporated development (urbanization) predictions from a habitat suitability model and the SLEUTH model of urbanization in the southeastern United States to estimate loss of suitable habitat in the future. This model was also used to predict changes to management that can influence the presence of white-tailed deer and invasive species and formed the foundation for three management-based scenarios. Management and conservation efforts include nonnative invasive species control measures, increase in deer harvest activities, and potential conservation actions (e.g., augmentation, establishment, or reintroduction of Ocmulgee skullcap within its historical range). Scenario 1 modeled a decreased rate of management and conservation efforts. Scenario 2 modeled a status quo level of management of populations. Scenario 3 modeled an increase in management and conservation efforts across the species range.

Conclusions

Current Condition

The Ocmulgee skullcap currently occupies portions of the Ocmulgee River (Georgia) and Savannah River (Georgia and South Carolina) watersheds. Currently, there are 19 extant Ocmulgee skullcap populations, 13 in the Ocmulgee River watershed and 6 in the Savannah River watershed. Two presumed extirpations of occurrences within two extant populations have occurred in the Savannah River watershed. Ocmulgee skullcap populations are generally small; 3 extant populations contain 50 or more individuals and 14 have fewer than 20 individuals.

However, the resiliency of the majority (16 of 19) of populations across the range was determined to be low or very low. Only one population within the Ocmulgee Representative Unit (RU) exhibits moderate resiliency; and two populations within the Savannah RU exhibit moderate or high resiliency. The Ocmulgee skullcap has generally low resilience to stochastic events at the population level. The Ocmulgee skullcap is found in two non-contiguous watersheds) in two states and most populations do not experience connectivity to another population. We determined the Ocmulgee skullcap exhibits moderate representation and the species may currently be at risk of losing adaptive capacity. The species-level redundancy was determined to be reduced from historical condition and is characterized by multiple redundant populations.

Overall, the Ocmulgee skullcap current condition is characterized by low or reduced resilience, moderate representation and reduced redundancy. Additional conservation measures may be needed to improve the long-term viability for this species.

Future Condition

Projected urbanization and three plausible future scenarios (decreased, status quo, and increased levels of management) were evaluated to predict future Ocmulgee skullcap viability.
Under Scenario 1, management and conservation efforts (e.g., nonnative invasive species control and deer harvest) in the range of the species are expected to be reduced. In this scenario, resiliency is decreased for all populations and 10 populations are predicted to be extirpated by 2040. An additional population is predicted to be extirpated by 2060. All populations experience a decline in resiliency with one moderately resilient population remaining. Under Scenario 2, management on lands where the species occurs is expected to continue at the current level. In this scenario, resiliency is predicted to decrease for 31–42 percent of populations and five populations are predicted to be extirpated by 2040; six populations are predicted to be extirpated by 2060. Three populations with high or moderate resiliency remain under this scenario. Under

Scenario 3 (increased management), resiliency changes are mixed, but overall there is an increase in population resiliency. However, one population is predicted to be extirpated by 2040 and three populations are predicted to be extirpated by 2060 in this scenario.

Under all three plausible future scenarios, loss of at least one Ocmulgee skullcap population is predicted. Representation is predicted to decline under all scenarios with extirpation of populations. Under Scenario 1, three populations are lost at the most upstream (two populations) and downstream (one population) extent of the species range in the Savannah River watershed, reducing the extent of the species range. Redundancy is predicted to decline under scenarios 1 and 2, with an increase in redundancy predicted under an increased management scenario. The status quo scenario results in predicted declines in resiliency, representation, and redundancy and additional conservation measures may be needed to improve the long-term viability for the Ocmulgee skullcap.

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CHAPTER 1. INTRODUCTION AND ANALYTICAL FRAMEWORK

1.1 Background and Previous Federal Actions

This report summarizes the results of a Species Status Assessment (SSA) conducted for *Scutellaria ocmulgee* (Ocmulgee skullcap), hereafter Ocmulgee skullcap. In this chapter, we discuss the previous Federal actions including petition history for Ocmulgee skullcap and the analytical framework used to evaluate the status of the species.

Ocmulgee skullcap is an herbaceous perennial plant found only in the Savannah River (South Carolina and Georgia) and the Ocmulgee River (Georgia) watersheds. Ocmulgee skullcap was initially recognized as a ”probably extinct” species in the U.S. Fish and Wildlife Service's (Service) first plant notice on July 1, 1975 (40 FR 27823). On September 27, 1985 (45 FR 39526-395848), Ocmulgee skullcap was identified as a category 1* species -"taxa whose status in the recent past is known, but that may already have become extinct." On February 1, 1990 (55 FR 6184-6229), Ocmulgee skullcap was changed to a category 2 species – "taxa for which there is some evidence of vulnerability, but for which there are not enough data to support listing proposals at this time." On February 28, 1996, the Service discontinued the designation of category 2 species as candidates for listing (61 FR 7596).

On April 20, 2010, the Service was petitioned to list 404 riparian and wetland species, including Ocmulgee skullcap, in the southeastern United States as endangered or threatened under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543; Act) and designate critical habitat (CBD 2010, entire). On September 27, 2011, the Service published a 90-day finding, which determined that the petition contained substantial information indicating the Ocmulgee skullcap may warrant listing (76 FR 59836). The Service now is required to make a 12-month finding on whether the species is warranted for listing, and therefore, a review of the status of the species was initiated to determine if the petitioned action is warranted. Based on the status review, the Service will issue a 12-month finding for the Ocmulgee skullcap.

Thus, we conducted an SSA to compile the best available data regarding the species' biology and factors that influence the species' viability. The SSA report for the Ocmulgee skullcap is a summary of the information assembled and reviewed by the Service and incorporates the best scientific and commercial data available. This SSA report documents the results of the comprehensive status review for the Ocmulgee skullcap and will be the biological underpinning of the Service's forthcoming decision on whether the species warrants protection under the Act.

1.2 Analytical Framework

Using the SSA Framework (Service 2016, entire), this SSA report provides an in-depth review and evaluation of its biological status and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available and to support all functions of the Service's Endangered Species Program. As such, the SSA report will be a living document that may be used to inform Endangered Species Act decision making, such as listing, recovery, Section 7, Section 10, and reclassification (the latter four decision types are only relevant should the species warrant listing under the Act).

For the purpose of this assessment, we define viability as the ability of Ocmulgee skullcap to maintain populations in calcareous hardwood forest ecosystems over time. To assess viability, we use the conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 308-311). To sustain populations over time, a species must have the capacity to withstand:
(1) environmental and demographic stochasticity and disturbances (Resiliency),
(2) catastrophes (Redundancy), and
(3) novel changes in its biological and physical environment (Representation).

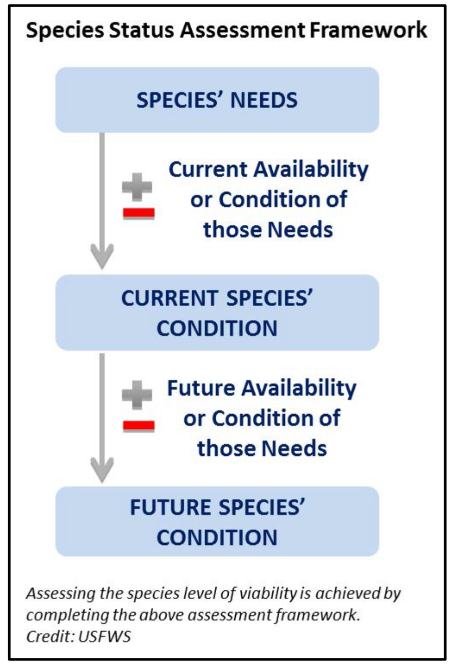

Figure 1-1. Species Status Assessment Framework.

A species with a high degree of resiliency, representation, and redundancy (the 3Rs) is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith et al. 2018, p. 306). To evaluate the viability of the Ocmulgee skullcap, we estimated and predicted the current and future condition of the species in terms of its resiliency, representation, and redundancy.

Resiliency is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

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

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

We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which might include measures of interpopulation genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess (1) natural levels and patterns of gene flow, (2) degree of ecological diversity occupied, and (3) effective population size. In our species status assessments, we assess all three facets to the best of our ability based on available data. For Ocmulgee skullcap, we do not have genetic diversity information. Therefore, we focused our assessment of species' representation based on the geographic and ecological variability of Ocmulgee skullcap.

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

This SSA Report provides a thorough assessment of the biology and natural history of the Ocmulgee skullcap and assesses demographic risks, stressors, and conservation factors in the context of determining the viability and risk of extinction for the species. Importantly, the SSA Report does not result in, nor predetermine, any decision by the Service under the Act. In the case of Ocmulgee skullcap, this SSA report does not determine whether the species warrants protections of the Act, or whether it should be proposed for listing as endangered or threatened species under the Act. The Service will make that decision after reviewing this report, along with supporting analysis, and any other relevant scientific information, and all applicable laws, regulations, and policies. The results of a decision will be announced in the *Federal Register*.

CHAPTER 2. SPECIES ECOLOGY AND NEEDS

In this chapter, we briefly describe Ocmulgee skullcap taxonomy and discuss the species' life history characteristics at the individual, population, and species levels. This is not an exhaustive review of the species' natural history; rather, it provides the information relevant to understanding the ecological basis for the SSA analyses conducted in Chapters 3 to 5.

2.1 Species Taxonomy, Description, and Identification

Ocmulgee skullcap (*Scutellaria ocmulgee*) was first described as a new species in 1898 (Small 1898, pp. 134-151) based on a specimen collected along the Ocmulgee River in Bibb County, Georgia. The Service is not aware of any known synonyms.

Ocmulgee skullcap is a member of the Lamiaceae (mint) family and a perennial herb with 4-sided stems that grows up to 16 to 32 inches (in) (40 to 80 centimeters (cm)) tall. The upper stem has two types of hairs: (1) pointed, upwardly-curved hairs and (2) longer, straight, knob-tipped hairs (Figure 2-1). A 10x hand lens is needed to distinguish both types of hairs. Its leaves are up to 3 in (7.6 cm) long, opposite, with rounded teeth and soft hairy lower surfaces. The lower leaves are heart-shaped with rounded bases; the upper and mid-stem leaves are oblong to oval with truncate or tapered bases. The leaf stalks of mid- and lower stem leaves are about half as long as the leaves. Its flowers are 3/4 to 1 in (1.8 to 2.3 cm) long, with an erect tube, hood-like upper lip, and a down-curved, white-striped lower lip; it is blue-violet colored and faintly fragrant (Figure 2-2). As with all members of this genus, the calyx has a bump on the upper side. Fruits consist of four tiny nutlets (seeds) enclosed by the calyx (Chafin 2008, entire; Patrick et al. 1995, pp. 173-174).

Scutellaria ocmulgee is currently recognized as a valid taxon, and the currently accepted classification is:

Class: Magnoliopsida
Order: Lamilaes
Family: Lamiaceae
Species: *Scutellaria ocmulgee*

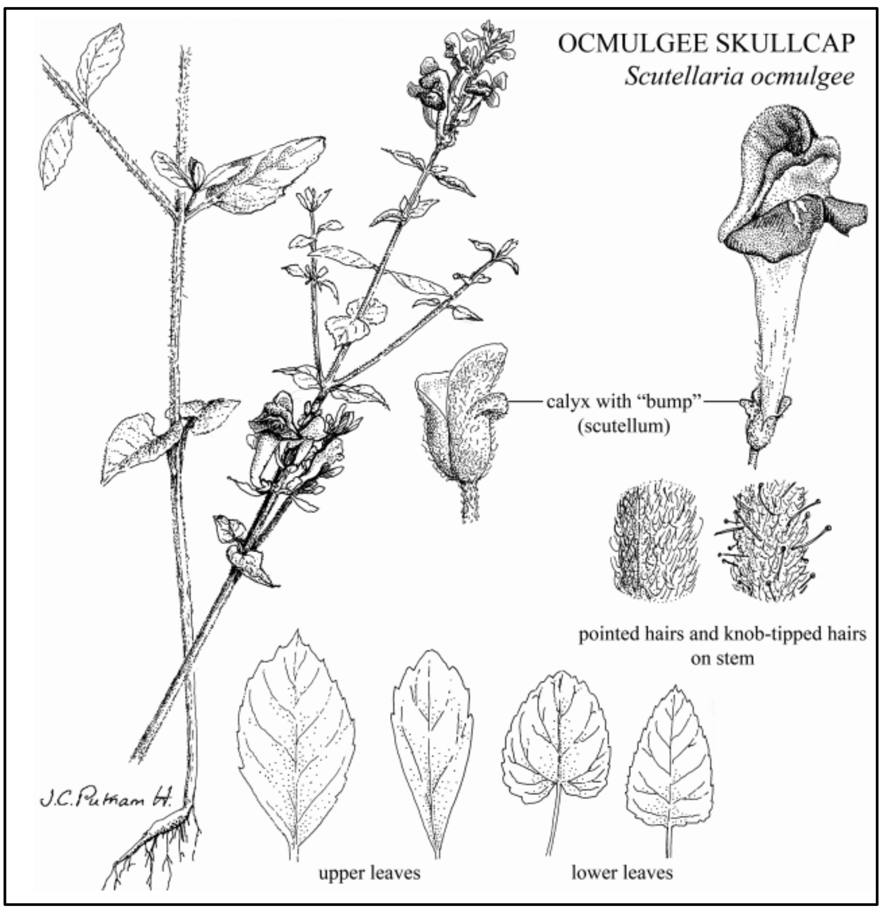

Figure 2-1. Botanical illustration of Ocmulgee skullcap. Illustration by Jean C. Putman; courtesy of Linda Chafin, State Botanical Garden of GA.

Figure 2-2: Ocmulgee skullcap in habitat.
Credit: Keith Bradley

Although taxonomy for Ocmulgee skullcap has been consistent through time, identification of the species is difficult (Morris et al. 2000, p. 28, Bradley 2019, p. 8). Prior to 2018, surveys for Ocmulgee skullcap identified the range and distribution to occur in the Flint, Ocmulgee, Oconee, Ogeechee river watersheds in Georgia and in the Savannah River watershed in South Carolina (see Section 2.2 Range and Distribution). In 2018, surveys for Ocmulgee skullcap were conducted in the five watersheds and found the Flint, Ogeechee, and Oconee watersheds, as well as, the southern reaches of the Savannah and Ocmulgee watersheds were occupied by *Scutellaria mellichampii*, not Ocmulgee skullcap (Figure 2-3) (Bradley 2019, entire).

Therefore, a new taxonomic key was published to better distinguish between these two *Scutellaria* species. Details of how this key was developed can be found in Bradley 2019 (entire) and Weakley et al. (2020, pp. 209-211).

Key to *S. ocmulgee* and *S. mellichampii*

1. Stipitate glands present on leaf margins and on veins throughout underside of leaf blade; upper portion of stem with dense stipitate glands and shorter, randomly spreading non-glandular hairs, leaves mainly cordate to truncate (to cuneate) .... *S. ocmulgee*
2. Stipitate glands absent on leaf margins and veins on underside of leaf blade (sometimes sparse near petiole); upper portions of stem with zero to sparse stipitate glands and shorter, upwardly curled non-glandular hairs, leaves mainly cuneate to truncate (to subcordate) .... *S. mellichampii*

Using the new taxonomic key, multiple specimens were tested and confirmed from across the five watersheds. Although *Scutellaria* specimens from the Flint, Oconee, Ogeechee, lower Ocmulgee, and lower Savannah are taxonomically considered part of the Ocmulgee skullcap's published range, the best available scientific information at this time supports that *Scutellaria* specimens from the Flint, Oconee, Ogeechee, lower Ocmulgee, and lower Savannah watersheds are *Scutellaria mellichampii*. Therefore, we excluded these areas from the taxonomic entity (*S. ocmulgee*) that we are assessing and reviewing in this SSA and only considered the upper Ocmulgee and upper Savannah River portions of the previous historical range, as further discussed below in Section 2.2. Range and Distribution.

2.2 Range and Distribution

The known historical and current range of Ocmulgee skullcap includes Georgia and South Carolina. The reported locality of the first described specimen (Small 1898, pp. 134-135) is probably in error. As noted, the specimen label described the location as "Ocmulgee River Swamp, Below Macon" and was dated July 8-, 1895 (s.n., NY) (Collins 1976, p. 138; Morris et al. 1999, p. 27). However, Small wrote in his publication, "collected by the writer on the banks of the Ocmulgee River above Macon, Georgia, in July 1895 (Small 1898, p. 134-135). The species went unseen following the original specimen collection, and was considered extinct (Leonard 1927, pp. 737-738; Epling 1946, p.85; Collins 1976, pp. 6, 52). In the late 1970s, Ocmulgee skullcap was relocated along the Ocmulgee River on the north side of Macon, Georgia in Bibb County, most likely corresponding to the first-described specimen collection locality by Small (1898, entire), or at least very close to it (Morris et al. 2000, p. 27). In 1980, a population was located along the Savannah River in Augusta, Georgia in Columbia County (Morris et al. 2000, p. 27); this discovery represented a major range extension into a new watershed for Ocmulgee skullcap and the second occurrence ever reported.

In the late 1990s, several status surveys were conducted in parts of Ocmulgee skullcap's potential range. One survey was conducted along the Savannah River, from the Piedmont ecoregion in Lincoln County, Georgia downstream to the lower Coastal Plain ecoregion in Effingham County, Georgia (Morris et al. 1999, entire). Snow (1999, 2001, entire) surveyed along the lower portion of the Ocmulgee River and upper Altamaha River, from Ben Hill to Appling counties, Georgia. Additional surveys were conducted along the upper Ocmulgee near Macon (Morris et al. 2000, entire) and Oconee rivers (Cammack and Genachte 1999, entire). From these surveys, numerous new occurrences were reported, leading to 31 occurrences in Georgia (Morris et al., 2000, p. 28). No formal surveys had been conducted prior to 2018 in South Carolina, where it was reported with certainty from a single site in Aiken County in 1998 (Morris et al. 2000, p. 28; Bradley 2019, pp. 7, 21-24).

Pre-2018 (1898 – 2017), Ocmulgee skullcap occurrences were documented within the following five watersheds (Figure 2-3) as summarized by Bradley (2019, p .7):

1. **Ocmulgee River watershed (Upper and Lower)**, from the vicinity of Macon (Bibb County), south to Ben Hill County, Georgia
2. **Savannah River watershed (Middle and Lower)**, from the fall line at Augusta, Georgia/North Augusta, South Carolina to just above the Savannah, Georgia area (mainly on the Georgia side)
3. **Oconee River watershed (Lower)**, from Washington County to Wheeler County, Georgia. Confirmed in 2018 as *Scutellaria mellichampii.*
4. **Ogeechee River watershed (Upper)**, a single observation in Washington County, Georgia. Confirmed in 2018 as *Scutellaria mellichampii.*
5. **Flint River watershed (Upper)**, a single observation along the Flint River in Taylor County, Georgia. Confirmed in 2018 as *Scutellaria mellichampii.*

As discussed previously, surveys for Ocmulgee skullcap were conducted in 2018 at 132 sites across five watersheds in Georgia and South Carolina: Flint, Ocmulgee, Ogeechee, Oconee, and Savannah (Bradley 2019, entire). These surveys generated concern about the ability of surveyors to identify taxonomic distinctions between Ocmulgee skullcap and *Scutellaria mellichampii*, also noted previously by Morris et al. (2000, p. 32). Therefore, a new taxonomic key was introduced to better distinguish between the two *Scutellaria* species (see above, Bradley 2019 entire, Weakley et al. 2020, pp. 209-211. As a result, many *Scutellaria ocmulgee* occurrences surveyed in 2018 were reclassified to *S. mellichampii* resulting in 32 occurrences of Ocmulgee skullcap across two watersheds, the Savannah and Ocmulgee, in Georgia and South Carolina (Figure 2-3). Distribution within the watersheds is best described as extending just above the Fall Line region in the extreme lower Piedmont, and downstream about 80 miles into the Coastal Plain (Figure 2-3) (Bradley 2019, p. 73).

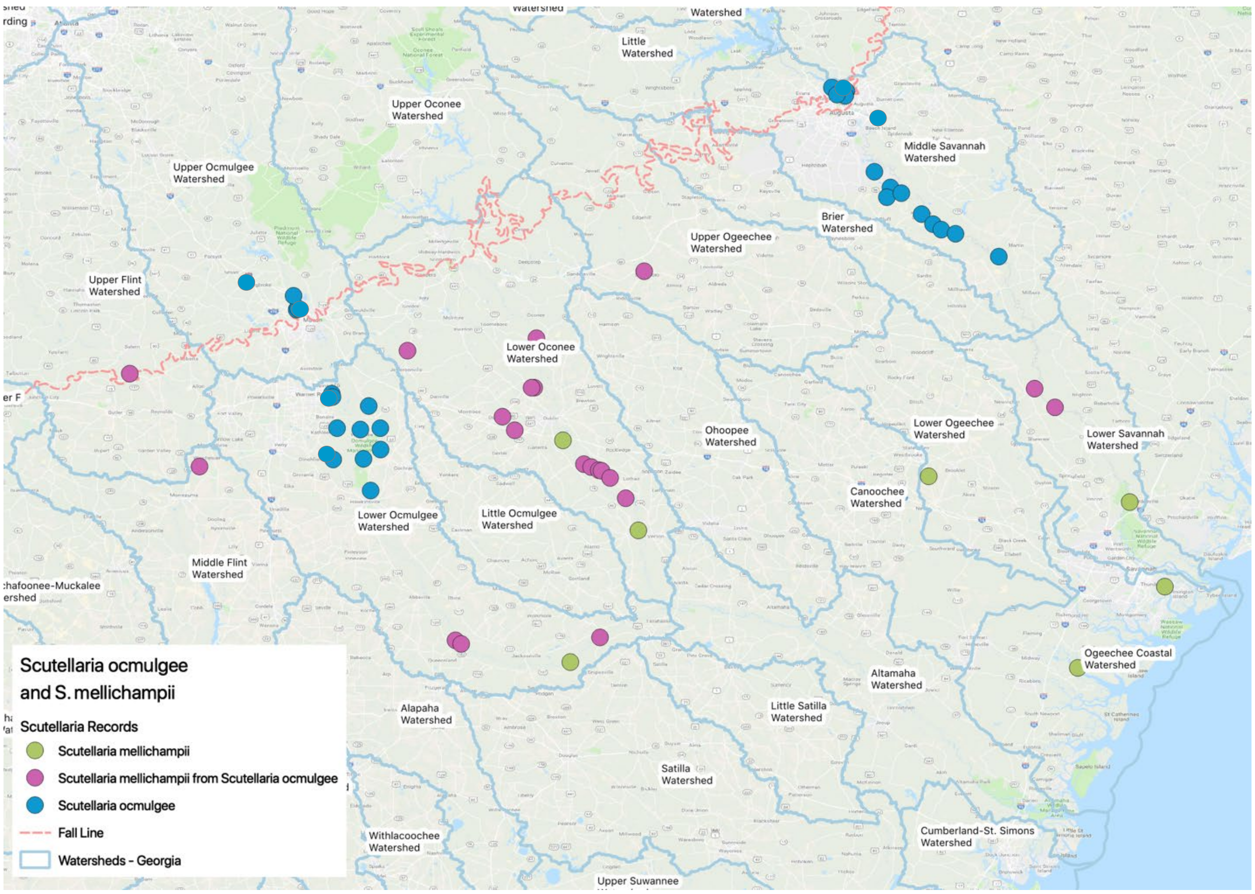

Figure 2-3: Reclassification of *Scutellaria* records post-2018 survey efforts. Map borrowed from Bradley (2019, p. 73) and edited to include all *S. ocmulgee* records from Georgia and South Carolina heritage program databases.

2.3 Habitat

Ocmulgee skullcap is found in moist, calcareous hardwood forests on north to northeast facing slopes of river bluffs and their floodplains in the Ocmulgee and Savannah River watersheds in Georgia and South Carolina. These calcareous forests are influenced by outcroppings of limestone or marl, with a diverse species composition ranging from short-lived pioneer species to long-lived shade tolerant species (Edwards et al. 2013, p. 406) (Figure 2-4). Communal species in these areas may consist of red buckeye (*Aesculus pavia*), Eastern redbud (*Cercis canadensis*), white oak (*Quercus alba*), basswood (*Tilia americana*), American holly (*Ilex opaca*), and relict trillium (*Trillium reliquum*) (Edwards et al. 2013, p. 409). Specifically, several occurrences co-occur with the endangered relict trillium (Bradley 2019, pp. 21-28).

Historical weather averages vary greatly where Ocmulgee skullcap occurs. Annual temperatures can vary from 1.67 degrees Celsius (°C) (35 degrees Fahrenheit (°F)) in January up to 33.3 °C (92 °F)) in July with an annual rainfall of more than 1.12 meters (m) (44 in). Although precipitation is anticipated throughout the year, the highest rainfall totals typically occur between December and March, and lowest historical amounts of precipitation occur in October and November (SERCC 2020, p. 2).

2.4 Life History and Individual Resource Needs

We relied on the knowledge of species experts along with the limited studies and field research for the species to develop the life cycle process and time frames for the life stages. Similar to other *Scutellaria* species, Ocmulgee skullcap reproduces sexually and is pollinated by bees, moths, butterflies, and sometimes flies and wasps (Figure 2-5) (Adams et al. 2010, p. 53, Cruzan 2001, pp.1577-1578). Adams et al. (2010, p. 53) reported over 35 different pollinator species for Ocmulgee skullcap with bee species being the most common pollinator. Differences in floral morphology and corolla color patterns of *Scutellaria* species may be the basis of recognition by pollinators (Collins 1976, p. 72).

Figure 2-5. Ocmulgee skullcap in flower with pollinator. Credit: Ed McDowell

The four life stages of Ocmulgee skullcap include seeds, seedling, vegetative plant (immature), and flowering plant (reproductive) (Figure 2-6). Throughout its range, Ocmulgee skullcap begins flowering in late June and can maintain its petals until October (Chafin 2008, p. 2). Core flowering period may occur late June until late July (Collins 1976, p. 138), as recent surveys indicated flowers were gone by August (Bradley 2019, p. 27). If pollination occurs, the plant develops up to four nutlets (seeds) maturing in 2–6 weeks (Collins 1976, p. 65). The seeds are released in the fall and usually overwinter from November through February, germinating in the following spring or summer (Collins 1976, p. 63). It is possible the plant can produce flowering that same year as germination (Collins 1976, p. 63), but it may take two years before the plant becomes sexually mature and produces seeds (Service 2018, entire). The lifespan of Ocmulgee skullcap plants is estimated to be between 5 and 8 years, with 3 to 6 years of potential viable seed production (Service 2018, entire).

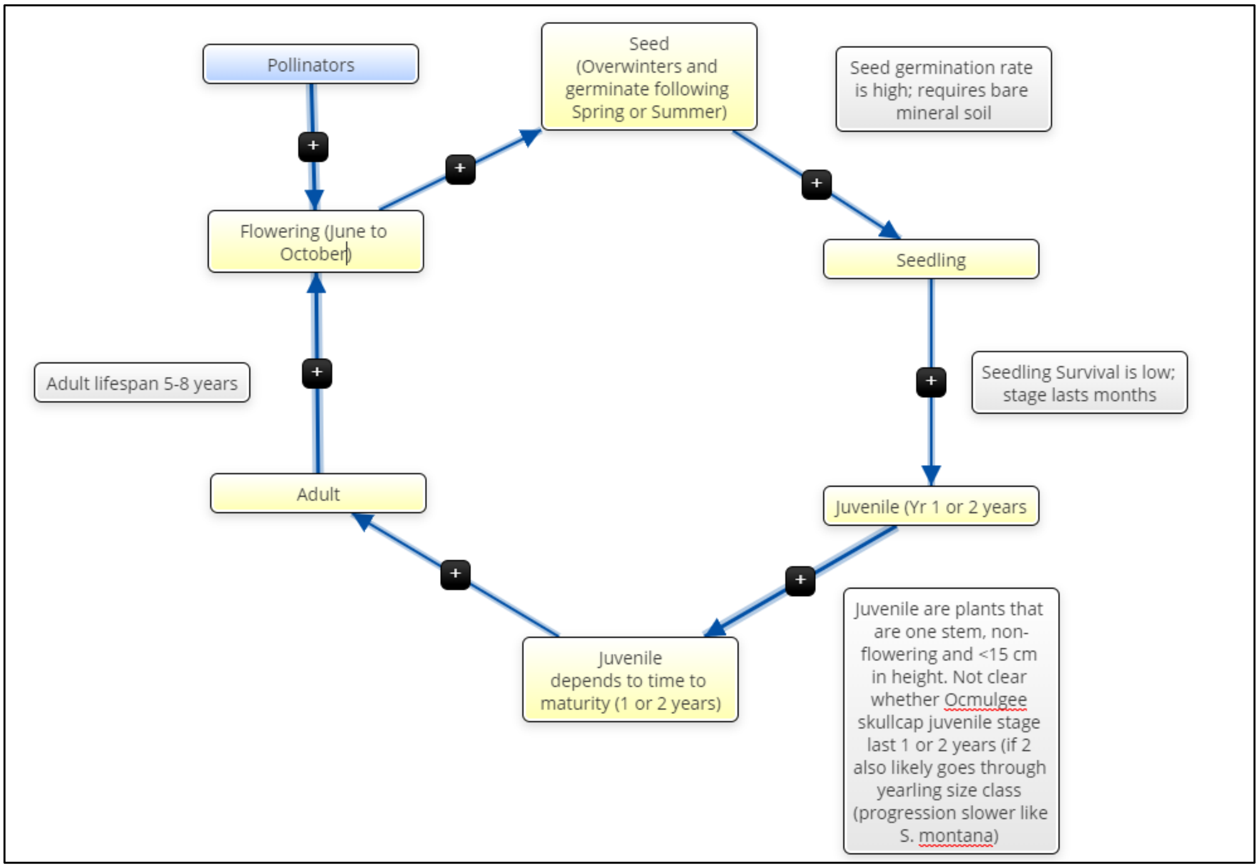

Figure 2-6. Life cycle stages for Ocmulgee skullcap: seed, seedling, vegetative plant (juvenile), and flowering plant (reproductive). Derived from Collins 1976 (pp. 63-65) and Service 2018 (entire).

The four life stages of Ocmulgee skullcap require very similar resources (Table 2-1). At the seed stage, the seed must dislodge from the calyx of the parent plant through disturbance of the stem (wind, rain, animal activity, etc.). The seeds must be deposited on bare soil that is rich in calcium and have partial shade provided by an upper canopy of mixed hardwoods. To germinate, the seed needs moisture (water), partial sunlight, and soil derived from limestone or marl *(*i.e. calcium rich). It is assumed that the smallest plants (< 15 cm (5.9 in)) with single stem and non-flowering are juvenile plants based on studies of other *Scutellaria* species (e.g., TDEC 2008, p. 2). Competition with other native species and nonnative invasive species can restrict seedlings, vegetative plants, and flowering plants from obtaining the three key resources (water, sunlight and soil) needed to grow and reproduce, and therefore, Ocmulgee skullcap needs limited competition. Vegetative and flowering plants require the same key resources: some undetermined amount of spring and summer precipitation, partial sunlight and soil derived from limestone or marl. Each individual plant reproduces sexually, and reproduction likely only occurs when the appropriate individual-level resource needs (i.e. water, sunlight, soil and limited competition) are met. A summary of the resource needs for Ocmulgee skullcap is provided in Table 2-1.

Table 2-1. Ocmulgee skullcap individual resources needs by life stage. H = Habitat, N = Nutrition, R = Reproduction, D = Dispersal. Key resource needs are in bolded text and include precipitation (water), partial sunlight, soil, and limited competition (Collins 1976; Chafin 2008).

Life stage	**Resource and/or circumstances needed for individuals to complete life stage**	**Resource function (HNRD)**
Seed	Fall/winter **precipitation**	N
	Bare mineral calcium-rich soil	H, N, R
	Partial **sunlight**	N
Seedling	Sufficient summer/fall **precipitation**	N
	Calcium-rich soil	H, N
	Limited competition from invasives/encroaching plants	H
	Partial **sunlight** for photosynthesis	N
Vegetative plant	Spring/summer **precipitation**	N
	Calcium-rich soil	H, N
	Limited competition from invasives/encroaching plants	H
	Partial **sunlight** for photosynthesis	N
Flowering plant	Spring/summer **precipitation**	N
	Calcium-rich soil	H, N
	Limited competition from invasives/encroaching plants	H
	Pollinators required	R
	Partial **sunlight** for photosynthesis	N

2.5 Population Needs

Population-level needs are an accumulation of the resource needs of individuals (Table 2-1). In addition to the individual-level needs, a population needs multiple individuals to reproduce, produce seed, germinate, and survive to replace individuals that have died to maintain a sustainable population size. In addition, there needs to be some level of connectivity between populations. Small population size (less than 100 individuals) can increase the risk of genetic drift (changes in allele frequency/disappearance of particular genes) and inbreeding depression (mating of related individuals) (Ellstrand and Elam 1993, pp. 218-219). Small population size and isolated populations offer limited nectar and pollen resources available to pollinators, making visitation to these sites more energetically expensive. Small, isolated populations of rare plant species often receive less pollinator visitation in comparison with larger or more widespread plant species (Ellstrand and Elam 1993, p. 227).

Resiliency is assessed at the population level and can be based on the number of individuals (i.e., abundance), colonization, recruitment, connectivity, and population growth. Seedlings have never been counted as part of routine monitoring; therefore, we have no information on the recruitment rate for this species. We do recognize that new recruits (seedlings) constitute a portion of the number of non-flowering, vegetative plants in any year, but do not have information to allow estimation of the percentage of the population in each age class. The metrics available for our assessment at the population level were; 1) the abundance of flowering and non-flowering plants, and 2) number of occurrences For example, we expect that both the number of flowering and non-flowering individuals in a population and the areas of occupied suitable habitat are positively related to viability and; thus, resiliency increases with these metrics.

2.6 Species Needs

In this section, we describe the metrics used to estimate and predict Ocmulgee skullcap viability at the species level in terms of redundancy and representation. Viability is a measure of the ability of Ocmulgee skullcap to sustain populations over time. Redundancy reflects the species' ability to withstand catastrophic events such that the number and distribution of populations are positively correlated with the redundancy metric. Representation reflects the species' adaptive capacity. Because we did not have genetic data for Ocmulgee skullcap, we used three proxy metrics to assess species' representation (Figure 2-7). To maintain high levels of representation, the species needs sufficient distinct variation of populations in terms of ecological settings (*e.g.* variation in watersheds and ecoregions), morphology, or phenology. The maintenance of this adaptive capacity, as reflected by variation in morphology, phenology, and ecological variation, is hypothesized to make the species' more robust in the face of future environmental changes. In summary, species-level viability for Ocmulgee skullcap is characterized by highly resilient populations distributed throughout the species' range (redundancy) with connectivity between populations to maintain adaptive capacity and ecological, morphological, or phenological variation (Figure 2-7).

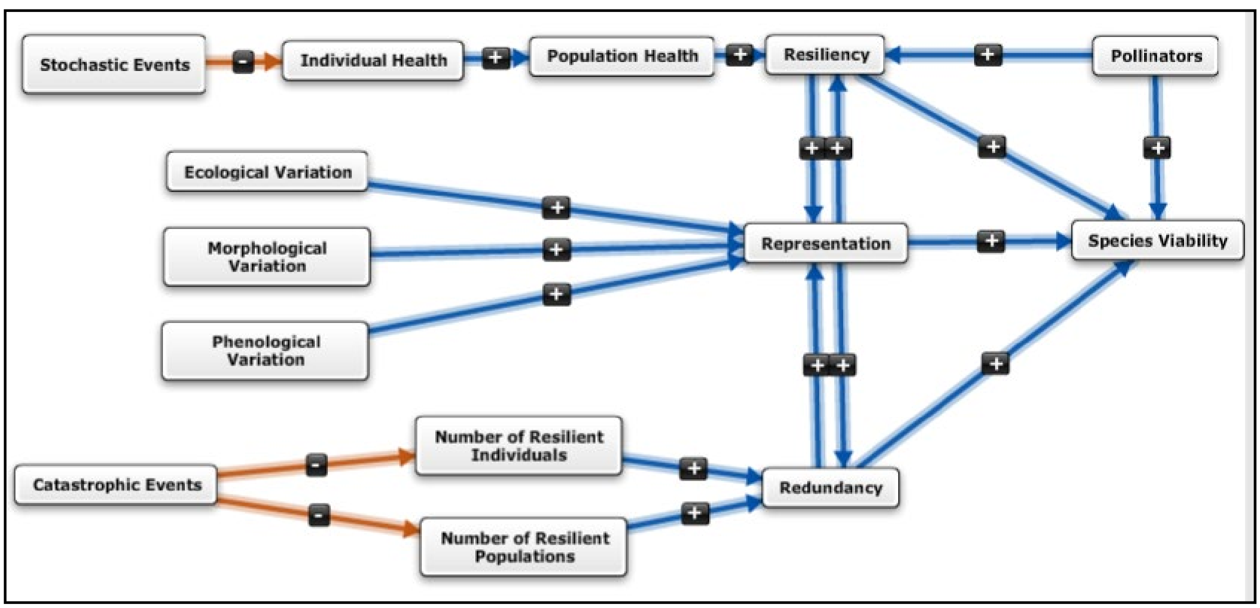

Figure 2-7. Ocmulgee skullcap (species) viability is composed of population resiliency, and species representation and redundancy.

CHAPTER 3. FACTORS INFLUENCING VIABILITY

The following discussion provides a summary of the influencing factors that are affecting or could be affecting the current and future condition of Ocmulgee skullcap throughout some or all of its range. Factors that are not known or not suspected to affect Ocmulgee skullcap individuals or populations, such as disease and impoundments, are not discussed in this SSA report.

3.1 Habitat Destruction and Modification

Historically, suitable habitat occupied by Ocmulgee skullcap has been lost or modified due to land conversion and development (Morris et al. 2000, pp. 31-32). One occurrence in the Savannah River watershed has been possibly extirpated due to land conversion in the form of pine plantations (Bradley 2019, p. 30), and two others have experienced altered conditions due to surrounding areas being developed (i.e. urbanization) (Bradley 2019, pp. 27-29). Urbanization can modify habitat conditions by introducing nonnative invasive species and increasing the amount and velocity of water runoff during precipitation events due to an increase of impervious surfaces. These factors reduce the availability of nutrients and soil conditions required for successful reproduction, as well as the ability of Ocmulgee skullcap to sustain populations over multiple seasons.

In addition, land use patterns near Ocmulgee skullcap occurrences can impact populations. Because Ocmulgee skullcap grows along steep slopes, when the tops of bluffs are logged or otherwise cleared for other land uses, runoff and erosion wash downslope and affect the species' habitat. This type of impact has been noted as problematic at five Ocmulgee skullcap occurrences (Morris 1999, p. 3).

Encroaching development has also decreased the amount and quality of forage and habitat for white-tailed deer (*Odocoileus virginianus*), which can increase the probability of foraging (i.e. herbivory) within Ocmulgee skullcap suitable habitat. Herbivory has been documented at numerous Ocmulgee skullcap sites (Bradley 2019, pp. 22-40). As development increases, the opportunity for hunting white-tailed deer decreases due to restrictions and proximity of residential homes, which can lead to increases deer populations and associated herbivory of Ocmulgee skullcap (see Section 3.4 **Herbivory** for more detail).

As the ecosystems where the species occurs have been converted to other land uses, this results in either the complete loss or destruction of Ocmulgee skullcap plants, its habitat, and the surrounding ecosystem or the habitat conditions become unsuitable and resource needs become unavailable for the Ocmulgee skullcap. Today, habitat destruction and modification from land conversion and development continues to be a factor influencing the viability of the Ocmulgee skullcap.

3.2 Competition from Other Species

Nonnative invasive plant species are documented at 8 of the 32 Ocmulgee skullcap occurrences (Bradley 2019, entire; Morris 1999, entire). Invasive plant species limit the available resources (nutrients and sunlight) necessary for Ocmulgee skullcap seedlings to become established, juveniles to mature, and flowering plants to reproduce on an annual basis. In turn, fewer plants are available to replace the mature plants as they reach the end of their life span leading to a decline in abundance of individuals in the population. Continued reductions in abundance may lead to population extirpation, particularly in small populations, and reduce the overall redundancy of Ocmulgee skullcap across a larger area.

Introduction and spread of nonnative invasive species often occur with development (i.e. encroachment due to urbanization) (McKinney 2002, p. 888), but can also be introduced from other types of adjacent land uses, such as agriculture (including timber land). The most problematic nonnative invasive species known to affect Ocmulgee skullcap populations are *Ligustrum sinense* (Chinese privet), *Elaeagnus umbellate* (autumn olive), *E. pungens* (thorny olive) *Microstegium vimineum* (Japanese stiltgrass), and *Lonicera japonica* (Japanese honeysuckle) (Morris et al. 2000, p. 31, Bradley 2019, p.77). On some sites, other nonnative invasive species, including *Pueraria montana* var. *lobate* (kudzu), *Vinca minor* (periwinkle), *Citrus trifoliata* (hardy orange), and *Pyrus communis* (common pear) pose local threats to individual occurrences and/or populations (Bradley 2019, p.77).

3.3 Collection and Harvest

Ocmulgee skullcap has not been widely tested or studied regarding the possible health benefits, however early work has investigated potential antioxidant and anti-tumor properties. One study in Georgia found air dried leaf extracts of Ocmulgee skullcap contained the highest total polyphenol (common antioxidant) content of the 20 *Scutellaria* species included (Vaidya et al. 2014, p. 45–46). Leaf extracts from Ocmulgee skullcap have demonstrated inhibitory properties against malignant gliomas (nerve tumor) as well (Parajuli et al. 2009, pp. 42, 47; Parajuli et al. 2011, p.2). Other species of *Scutellaria* have historically been used across other countries and Tribes within the United States. Health benefits investigated include anti-inflammatory, sedative, astringent, epilepsy, insomnia, anti-anxiety, and others (Joshee et al. 2002, pp. 580-581; Brock et al. 2014, pp. 696–698). An extract of the roots of a Chinese species (*S. baicalensis*) have been found to possess antiviral activities (Zandi et al. 2013, pp. 9–10). Based on the possible health benefits of Ocmulgee skullcap, overcollection in the future is a moderate possibility and should be monitored through the permit process of the States.

3.4 Herbivory

3.4.1 White-tailed Deer

Over the last century, white-tailed deer (*Odocoileus virginianus*) population numbers have increased substantially (Horsely et al. 2003, p. 1). White-tailed deer can be a major threat to endangered and threatened plants in the Southeast U.S. (Miller et al. 1992, entire) including impacts to species density, diversity, and composition and plant development (Horsely et al. 2003, p. 113). Immature stems of many *Scutellaria* species are often browsed by deer and this herbivory can prevent reproduction of that stem for the year (Bradley 2019, p.77). In addition, some individual plants may also be pulled from the ground during browsing. In *Scutellaria montana* populations, deer herbivory was found to have a potential positive influence where deer browsed on all vegetation and *S. montana* may have been “released” by the reduction in competing vegetation (Benson and Boyd 2014, p. 89). However, in 2018 surveys, deer herbivory was observed at every Ocmulgee skullcap site (and *S. mellichampii* sites), with major impacts on reproduction documented at some sites (Figure 3-1) (Bradley 2019, entire). Deer herbivory was also noted as impacting *Scutellaria* in the 1999 surveys (Morris 1999, p. 3; Snow 1999, p. 8).

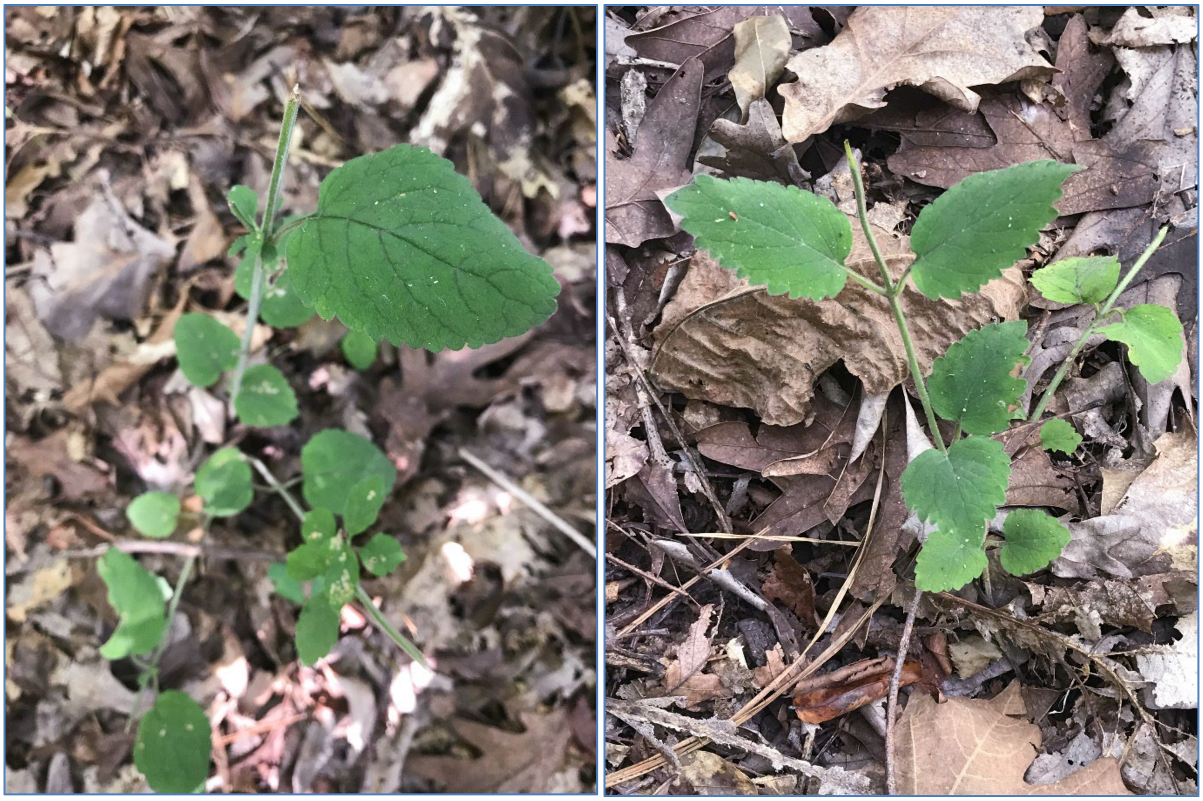

Figure 3-1: Herbivory of Ocmulgee skullcap plants. Credit: Keith Bradley.

Severe deer herbivory may have caused the extirpation of the Ocmulgee skullcap occurrence at the Savannah River Bluffs Heritage Preserve in Aiken County, South Carolina (Bradley 2019, p. 24). Because of intense public recreation at the preserve, deer harvest is not permitted within the preserve. In addition, neighbors from dense developments around the preserve feed deer, with some dumping large piles of deer corn (Bradley 2019, p. 24). This abundance of food and freedom from hunting has resulted in a very dense deer population. The former botanical "hot-spot" for Ocmulgee skullcap now has a depauperate, almost barren herbaceous layer. In addition, populations of the endangered *Trillium reliquum* (relict trillium) have been reduced due to deer herbivory. The direct impacts from white-tailed deer are widely noted across the entire range of the Ocmulgee skullcap at various levels (Bradley 2019, entire). Over 75% of the all survey data reviewed noted the presence of herbivory being a limiting factor for Ocmulgee skullcap populations.

Indirect impacts of deer density and herbivory, such as competition and facilitation of browse-resilient species, are a concern for preferred deer forage species (Horsely et al. 2003, p. 114). A 10-year study of deer impacts on vegetation in hardwood forests found increased deer populations resulted in reduced plant species diversity and increased browse-resilient plants or plants avoided by deer (Horsely et al. 2003, p. 115). At this time, the indirect impacts of deer herbivory on Ocmulgee skullcap are unknown; however, deer herbivory is known to directly impact several populations of the species.

3.4.2 Feral Hogs

To date, there are no recorded impacts from feral hogs (*Sus scrofa*) on Ocmulgee skullcap. However, it is reasonable to consider possible impacts to Ocmulgee skullcap individuals and the species' habitat from feral hog activity given both species can occur in the same habitat. These impacts may include the rutting of the soil around and within plants resulting in removal of the actual stem, as well as, localized increases in runoff and sedimentation from upslope foraging and rutting.

3.5 Climate Change

In the southeast United States, several climate change models have projected more frequent drought, more extreme air temperatures, increased precipitation (e.g., flooding), and more intense storms (e.g., frequency of major hurricane) (Burkett and Kusler 2000, p. 314; Klos et al. 2009, p. 699; IPCC 2013, pp. 3-29). When taking into account future climate projections for temperature and precipitation where Ocmulgee skullcap occurs, warming is expected to be greatest in the summer, which is predicted to increase drought frequency, while annual mean precipitation is expected to increase slightly, leading to a slight increase in flooding events (Figures 3-2 and 3-3) (IPCC 2013, entire; Alder and Hostetler 2013, unpaginated; USGS 2020, unpaginated).

To understand how climate change is projected to change where Ocmulgee skullcap occurs, we used the National Climate Change Viewer (NCCV), a climate-visualization tool developed by the U.S. Geological Survey (USGS), to generate future climate projections across the range of the species. The NCCV is a web-based tool for visualizing projected changes in climate and water balance at watershed, State, and county scales (USGS 2020, unpaginated). This tool uses air temperature and precipitation data from 30 downscaled climate models (Coupled Model Intercomparison Project Phase 5 (CMIP5)) for two Representative Concentration Pathway (RCP) scenarios, RCP 4.5 and RCP 8.5, as input to a simple water-balance model to simulate changes in the surface water balance over historical and future time periods, providing insight into potential for climate-driven changes in water resources. To evaluate the effects of climate change in the future, we used projections from RCP 4.5 and RCP 8.5 to characterize projected future changes in climate and water resources, averaged for the State of Georgia encompassing the majority of the range of the Ocmulgee skullcap. The projections estimate change in mean annual values for maximum air temperature (Figure 3-2), minimum air temperature, monthly precipitation (Figure 3-3), and monthly runoff, among other factors.

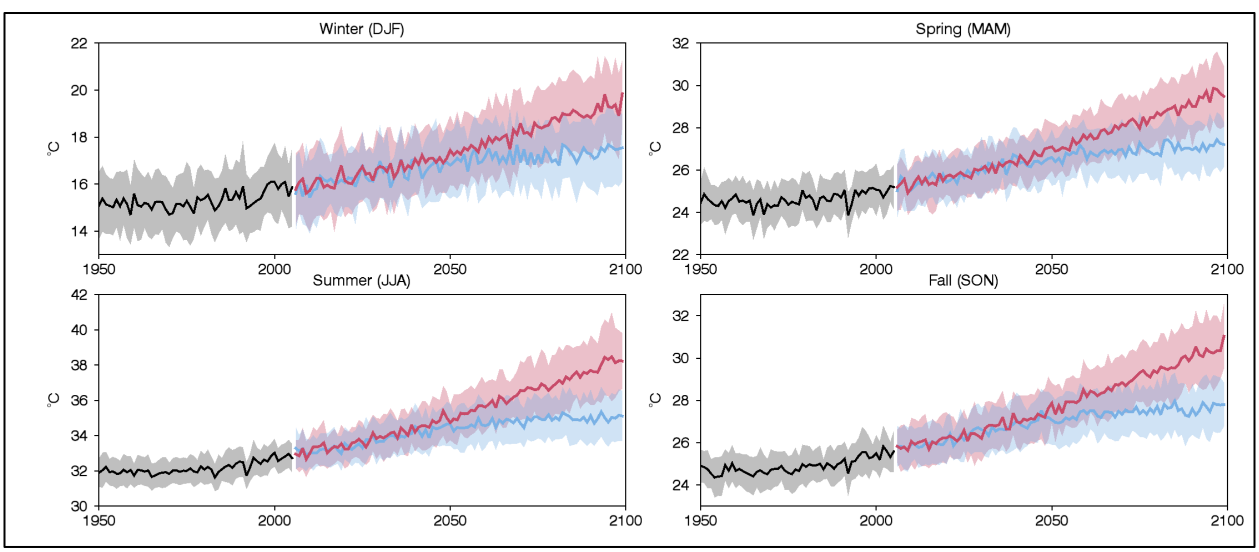

Figure 3-2. Time series of the seasonal average of maximum air temperature in the State of Georgia with historical (black), RCP 4.5 projection (blue), and RCP 8.5 projection (red). “The historical period ends in

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." Source: USGS National Climate Change Viewer (Credit: Alder and Hostetler 2013, unpaginated; Hostetler and Alder 2016, entire; Thrasher et al. 2013, entire).

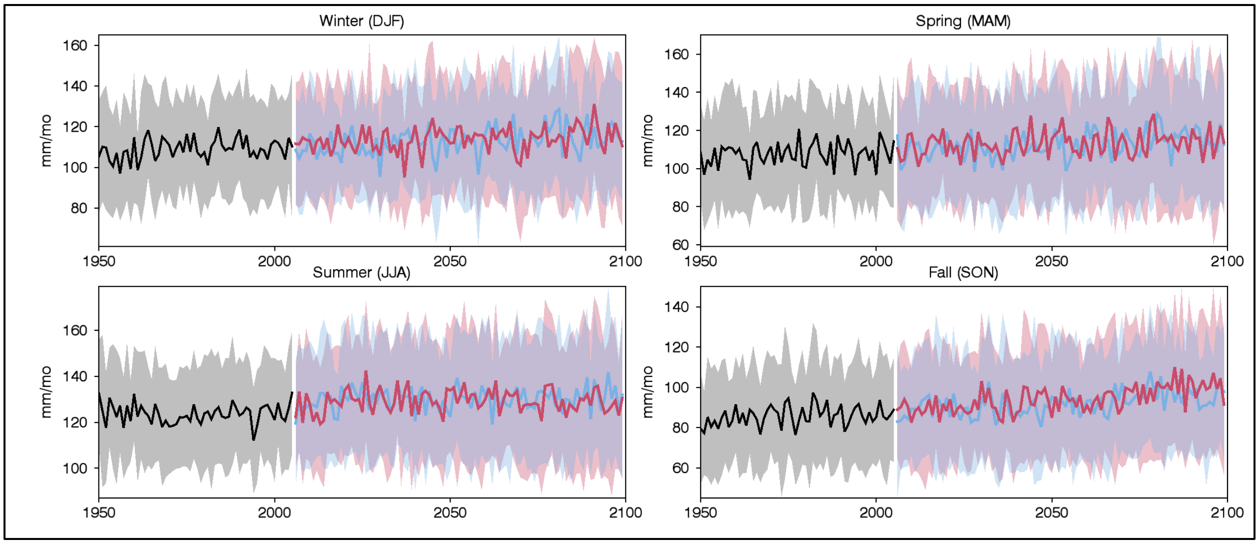

Figure 3-3. Time series of the seasonal average of precipitation in the State of Georgia with historical (black), RCP4.5 projection (blue), and RCP8.5 projection (red). "The historical period ends in 2005 and the future periods begin in 2006. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes." Source: USGS National Climate Change Viewer (Credit: Alder and Hostetler 2013, unpaginated; Hostetler and Alder 2016, entire; Thrasher et al. 2013, entire).

Within the range of the Ocmulgee skullcap, the NCCV projects that under the RCP 4.5 scenario, maximum air temperature will increase by 1.9 °C (3.4 °F), minimum air temperature will increase by 1.8 °C (3.2 °F), precipitation will increase by 5.36 millimeters (0.2 in) per month, and runoff will remain the same (USGS 2020, unpaginated). These estimates indicate that, despite projected minimal increases in annual precipitation, anticipated increases in maximum and minimum air temperatures will likely offset those gains. Based on these projections, Ocmulgee skullcap will on average be exposed to increased air temperatures across its range, despite limited increases in precipitation.

Within the range of the Ocmulgee skullcap, the NCCV projects that under the more extreme emissions scenario (RCP 8.5), maximum air temperature will increase by 2.8 degrees Celsius (°C) (5.0 degrees Fahrenheit (°F)), minimum air temperature will increase by 2.7 degrees C (4.9 °F), precipitation will increase by 5.36 millimeters (0.2 inches) per month, and runoff will remain the same (USGS 2020, unpaginated). These estimates indicate that, despite projected minimal increases in annual precipitation, anticipated increases in maximum and minimum air temperatures will likely offset those gains. Based on these projections, Ocmulgee skullcap will, on average, be exposed to increased air temperatures across its range, despite limited increases in precipitation. The increase of maximum and minimum temperatures and variability in precipitation will likely result in an increased probability of longer and more severe droughts in the future.

Within mixed hardwood forests where the species occurs, drought conditions due to higher temperatures and variable precipitation could reduce the available resources required for plant survival, increase the risk of negative effects from flooding and erosion, and limit the ability of Ocmulgee skullcap to produce viable seed and persist over time. Despite the recognition of climate effects on ecosystem processes, there is uncertainty within each model about what the exact climate future for the southeastern United States will be, and there is uncertainty in how the ecosystems and species will respond. Although there are several potential risks associated with long-term climate change as described above, there is uncertainty regarding the how the Ocmulgee skullcap will respond to these risks.

3.6 Pollinator Visitation and Reproduction

Ocmulgee skullcap populations may be experiencing reproductive problems, with poor seed set noted (Vaidya 2017, entire). However, information regarding Ocmulgee skullcap reproductive biology is currently limited. Work on a closely related congener, *S. montana*, shows that the species has very low seed set and very low visitation by pollinators (Cruzan 2001, p. 1577). These factors may reduce the plants ability to exchange genetic material between individuals within the same population, as well as reduce exchanges between populations. Limited genetic exchange can lead to a decrease of the species' ability to adapt as conditions change over time and ultimately, cause localized population or occurrence extirpations.

3.7 Conservation Measures

3.7.1 Management of White-tailed Deer and Nonnative Invasive Species

Currently, in areas where hunting of white-tailed deer is relatively frequent (annual), the presence of deer herbivory on Ocmulgee skullcap is less than in areas with limited hunting. Hunted areas have reflected more flowering individuals, as well as less overall evidence of herbivory (e.g. Bradley 2019, p. 22). An established white-tailed deer hunting program in areas where Ocmulgee skullcap is present will likely lead to an increase in resiliency for Ocmulgee skullcap populations (Morris 1999, p. 3; Bradley 2019, p. 78).

Nonnative invasive plant species have been documented in multiple Ocmulgee skullcap populations (Bradley 2019, pp. 22-40). Presence of nonnative invasive species indicates competition for resources (e.g. soil nutrients, water, and sunlight) needed for Ocmulgee skullcap to persist and reproduce. Management of invasive nonnative plant species in and near Ocmulgee skullcap populations may also lead to an increase in overall population resiliency.

3.7.2 Protected Lands

Protected lands include lands that are State or Federally-owned and conservation easements owned or protected by conservation organizations. These properties buffer against the impact of habitat loss and modification due to development. In addition, populations occurring on protected lands are more likely to receive conservation management, such as white-tailed deer hunting and nonnative invasive species management. Therefore, the impact of nonnative invasive plants species and white-tailed deer herbivory (browsing) may be reduced for populations that occur on State and Federal lands and lands with conservation easements.

Currently, Ocmulgee skullcap occurs on Federal land, State, and county lands as well as lands held by a Land Trust in a conservation easement. In Georgia, Ocmulgee skullcap occurs on Robins Air Force Base where the Integrated Natural Resource Management Plan includes species monitoring and vegetation management is expected to benefit the species (mowing in winter) (Robins AFB INRMP 2017, p. 83). The species also occurs on three State Wildlife Management Areas (WMAs) in Georgia: Yuchi, Ocmulgee and Oaky Woods WMAs. Ocmulgee skullcap is listed as a high priority species (i.e. Species of Great Conservation Need (SGCN)) in the Georgia State Wildlife Action Plan (GA SWAP 2015). The species also occurs in Columbia County, Georgia, on land owned by Richmond County. It is not clear what the conservation potential is for this site. In South Carolina, the species is known to occur on the Greystone Preserve, which is protected by the Central Savannah River Land Trust. In addition, the species has been documented on the State-owned Savannah River Bluffs Heritage Preserve.

Table 3-1: Federal, State, County and Land Trust lands where Ocmulgee skullcap occurs.

State	Ownership	Site Name
Georgia	State	Oaky Woods WMA
Georgia	State	Ocmulgee WMA
Georgia	State	Yuchi WMA
Georgia	Richmond County	Adjacent to Savannah Rapids Park
South Carolina	State	Savannah River Bluffs Heritage Preserve
South Carolina	Central Savannah River Land Trust	Greystone Preserve

3.7.3 State Protections

Ocmulgee skullcap is listed as State threatened in Georgia (Patrick et al. 1995, pp. 173-174) and is not listed in South Carolina. In Georgia, the Georgia Wildflower Preservation Act of 1973 provides limited protections for “protected species,” defined as “a species of plant life which the department shall have designated as [protected]…” and “protected species” growing on any public lands are protected from cutting, digging, pulling, or removing unless the Georgia Department of Natural Resources has authorized such acts (Georgia Code 2015). In South Carolina, the South Carolina Nongame and Endangered Species Conservation Act of 1974 covers only animals and provides no protection for plants on any lands in South Carolina (South Carolina Code 1974).

3.8 Synergistic Effects

In addition to factors impacting Ocmulgee skullcap individually, many populations are currently exposed to multiple factors concurrently or are expected to be exposed to multiple factors concurrently in the future and these factors may act on the species synergistically. The combined impact of multiple stressors is likely more harmful than a single stressor acting alone. During the 2018 survey efforts, several populations were noted to be experiencing herbivory by white-tailed deer and competition from nonnative invasive species. It is likely the effects of the factors on these populations represent what is occurring across the range of Ocmulgee skullcap as well. The impacts from encroaching development and/or climate change on these same Ocmulgee skullcap populations may increase the negative influence of white-tailed deer and nonnative invasive species on Ocmulgee skullcap viability. These cumulative effects could result in extirpations of Ocmulgee skullcap populations across the range.

3.9 Summary of Factors Influencing Viability

We reviewed and summarized the factors that may influence the viability of Ocmulgee skullcap (Figure 3-4). Concerns about Ocmulgee skullcap's viability focused on the following factors: (1) habitat destruction and modification; (2) competition from other species, (3) collection and harvest; (4) herbivory; (5) climate change, and (6) pollinator visitation and reproduction. The primary factors currently impacting the viability of Ocmulgee skullcap are deer herbivory and habitat destruction and modification resulting from development (i.e., urbanization). In addition, these impacts will be further exacerbated as urbanization increases, presence of nonnative invasive species, and climate change in the future.

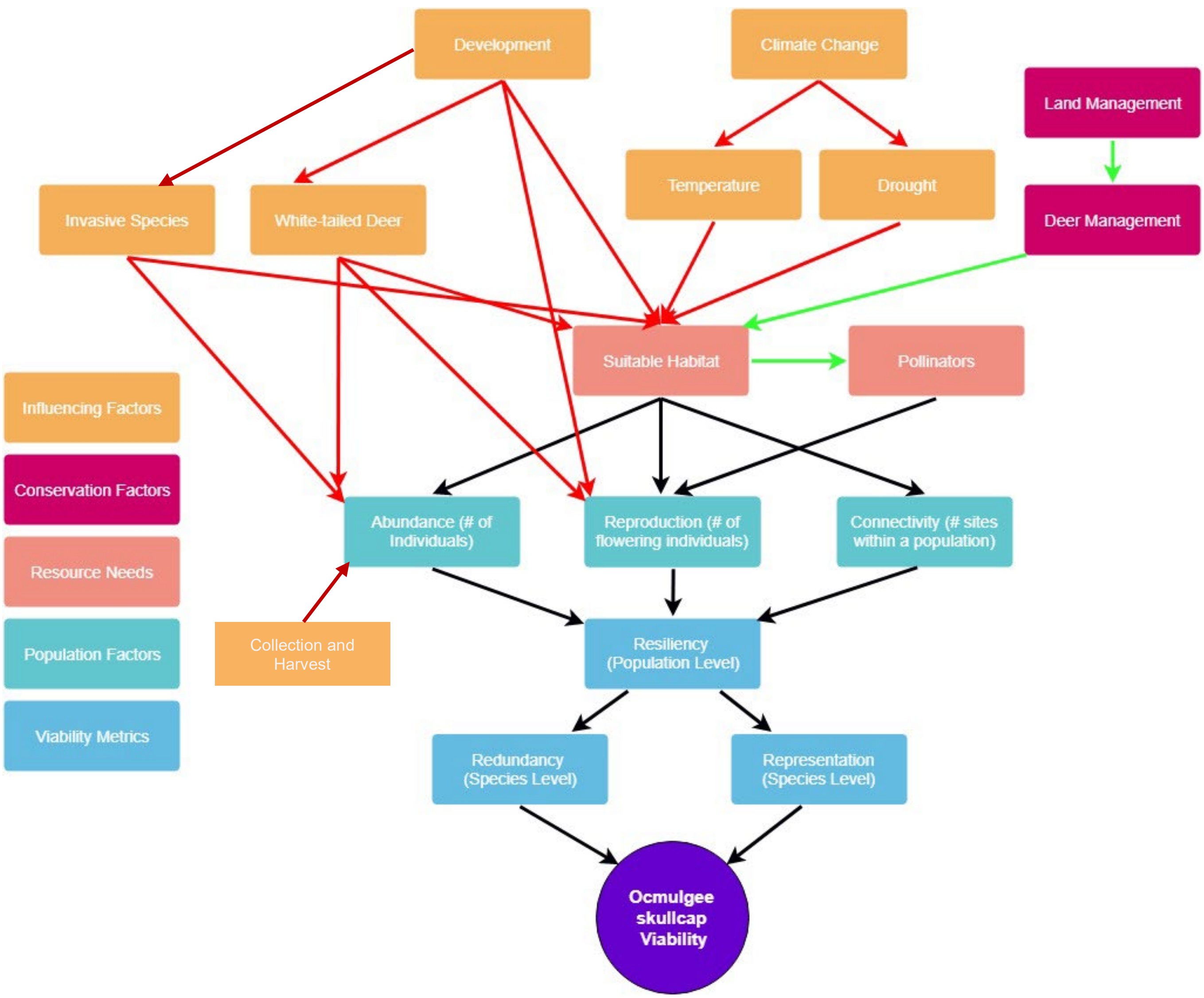

Figure 3-4. Influence diagram for the Ocmulgee skullcap showing relationships between factors and species' viability. Factors connected by red arrows have negative relationships. Factors connected by green arrows have positive relationships. Factors connected by black arrows may have either a positive or negative relationship.

CHAPTER 4. CURRENT CONDITION

In this chapter, we consider what the Ocmulgee skullcap needs for viability. First, we define what constitutes a population for Ocmulgee skullcap. Next, we characterize the species needs in terms of resiliency (population level), representation (species level), and redundancy (species level) (the 3Rs). Finally, we estimate the current condition of Ocmulgee skullcap based on the population and habitat metrics used to characterize the 3Rs.

4.1 Delineating Populations

Populations are the basic analytical unit in which resiliency is assessed. Based on expert recommendations (Service 2018, entire), we used NatureServe's Habitat-based Plant Element Occurrence Delineation Guidance (NatureServe 2020, entire) 2-kilometer (km; 1.24 miles (mi)) separation distance rule to delineate each population for this assessment. Using ArcGIS, we buffered each of the 26 known occurrences by 2 km. Occurrences with overlapping buffers were considered within the same population (Figure 4-1).

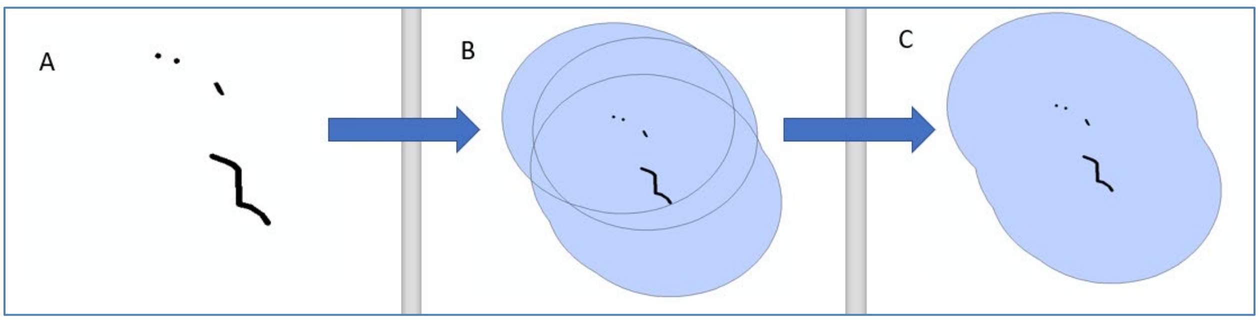

Figure 4-1. Example of delineating populations using the 2-km separation rule. Occurrences ≤ 2 km apart are considered part of the same population, (A) occurrences, (B) occurrences with overlapping 2-km buffers, and (C) delineated population.

Species occurrence data are documented over time as geographic areas that can be displayed in a Geographic Information System and represent unique observations of Ocmulgee skullcap at specific dates in time. Rangewide occurrence data used for this assessment was from the State Heritage programs in Georgia and South Carolina and included 2018 survey efforts from Bradley (2019, entire).

4.2 Populations

Overall, 32 Ocmulgee skullcap occurrence records exist rangewide from years 1961-2020. Using the 2-km buffer delineation, 19 populations were identified within the current known range of Ocmulgee skullcap. Of the 19 populations, all are currently extant with thirteen populations occurring within the Ocmulgee River watershed (Ocmulgee populations) and six within the Savannah River watershed (Savannah populations) (Figure 4-2). There have been two presumed extirpations of occurrences in the Savannah watershed due to severe deer browsing in the CAR population and land conversion (planting pine plantation) in the BUN population. In the CAR population, the Savannah Natural Heritage Preserve occurrence was not observed during surveys in 2018 and 2019 (Bradley 2019, Service2020). In the BUN population, the Boggy Gut Creek occurrence was last observed in 1999, but the entire site was clearcut in 2005, planted in loblolly pine, and subsequently cut in 2014 and 2017. The site is considered possibly extirpated (Bradley 2019, p. 30). See Appendix A for details regarding which occurrences make up each population and population definitions.

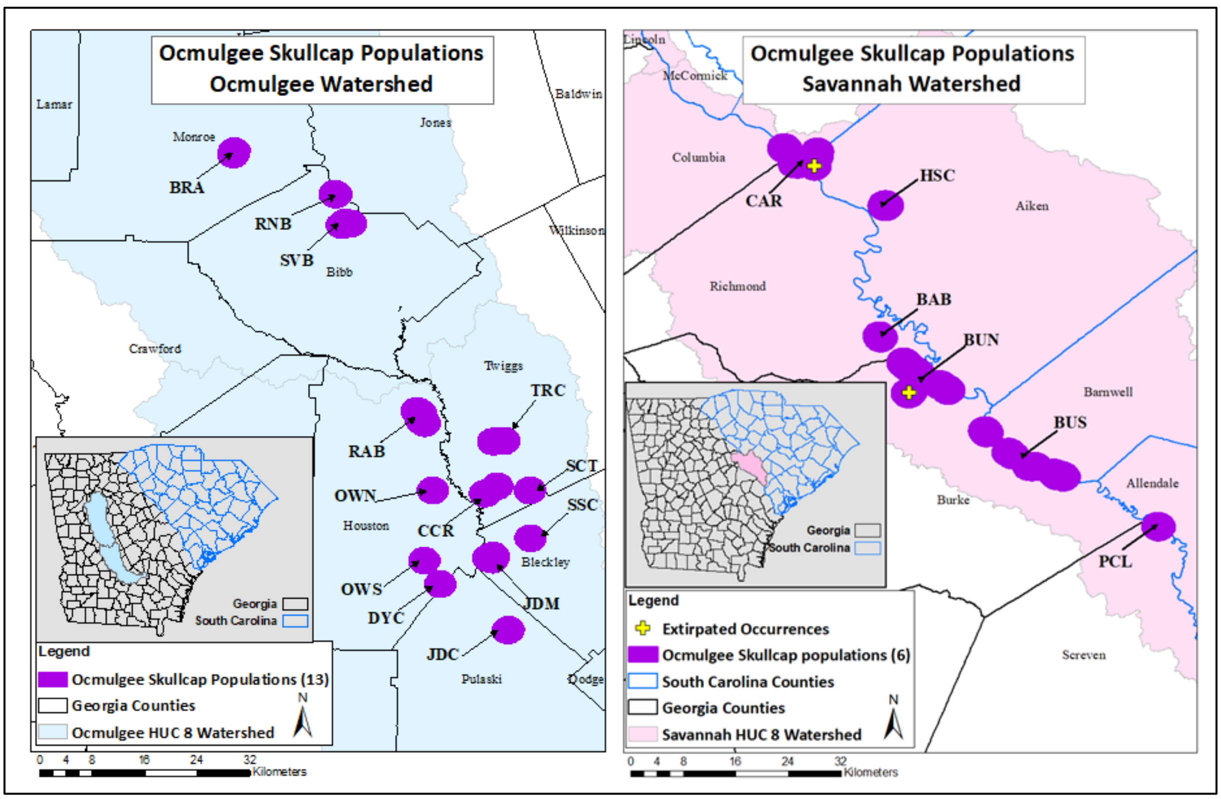

Figure 4-2. Distribution of the 19 Ocmulgee skullcap populations across the range. The purple circles represent the populations. Yellow crosses are the presumed extirpated occurrence records in the Savannah watershed. Colored polygons represent the hydrologic unit (HUC 8) watersheds with Ocmulgee populations on the left and Savannah populations on the right. Definitions of population codes can be found in Table 4-3 and Appendix A. (Note: both upper and lower Ocmulgee River HUC 8s are combined into one representative unit for the Ocmulgee populations throughout this document.)

4.3 Methods for Estimating Current Condition

Using the SSA framework, we used resiliency, representation, and redundancy (the 3Rs) to assess the viability of the species. For Ocmulgee skullcap, we described species-specific viability as the ability of the species to sustain populations in mixed-hardwood ecosystems with calcium rich soils over time. For this assessment, we described the current condition of the species and predicted a range of plausible future scenarios and future conditions (Chapter 5) using the 3Rs.

4.3.1 Population Resiliency

Resilient populations of Ocmulgee skullcap should be robust to normal stochastic events or disturbances (fire, weather, natural fluctuations in productivity, etc.). We identified high resiliency for populations of this species as a population exhibiting the following characteristics: sufficient number of individuals to sustain the population, multiple occurrences within a population, and high-quality habitat. We hypothesized that there is a negative relationship between populations with high resiliency and the probability of localized events causing populations to become extirpated. Our method for assessing demographic and habitat metrics to determine the current resiliency of Ocmulgee skullcap populations is described in detail below.

<u>Resiliency - Metrics Assessed</u>

We considered a total of five resiliency metrics, four demographic and one habitat, to estimate the current resiliency of Ocmulgee skullcap populations: (1) number of individuals within a population, (2) number of flowering individuals (reproductive adults) within a population, (3) number of occurrences within a population, (4) change in number of occurrences within a population over time, and (5) condition of native groundcover.

In terms of Ocmulgee skullcap population needs, multiple individuals need to reproduce and survive to replace individuals that have died in a population (i.e., avoid a net loss or negative growth rate). Small, isolated populations are less likely to be visited by pollinators due to the limited resources available to pollinators. Ocmulgee skullcap's reproductive success relies on cross-pollination, and larger, connected populations receive more frequent pollinator visitation (Ellstrand and Elam 1993, p. 227). Therefore, the number of occurrences per population, the number of flowering individuals within a population, and the number of individuals within a population were demographic metrics we considered for assessing population resiliency. However, after collating the available occurrence record information, we decided to eliminate the number of flowering individuals within a population as one of the demographic metrics used in the analysis because few occurrences had the necessary data to assess this metric.

Habitat factors such as native herbaceous ground cover condition can influence the ability of Ocmulgee skullcap to grow, reproduce, and survive. To capture important aspects of this metric, which is directly related to growth, survival, and reproductive success, two factors that characterize the quality and quantity of native herbaceous ground cover were assessed: (1) presence of nonnative invasive plant species and (2) presence of deer herbivory (browsing) (Table 4-1). As described above in section 3.4 Herbivory, Ocmulgee skullcap is a preferred forage species for white-tailed deer, which limits the plant's ability to reach maturity and reproduce as well as survive. Furthermore, nonnative invasive plant species compete with Ocmulgee skullcap for soil, nutrients, and sun exposure, which slows down or prevents development of individual plants.

To estimate overall population resiliency, each demographic and habitat metric was assigned resiliency scores (ranging from 0 to 3), ultimately resulting in four scores. On our constructed scale of 0 to 3, 3 was considered to be a *high condition score*, 2 was considered a *moderate condition score*, 1 was considered a *low condition score*, and 0 was considered a *very low condition score*. Condition scores were assigned for each demographic and habitat metric for each population using data obtained from the Georgia Department of Natural Resources Heritage Program, South Carolina Natural Heritage Program and from survey reports by Morris (1999, entire) and Bradley (2019, entire) (Appendix A). In addition, for populations that have not been observed recently (2018 or later) aerial imagery spanning multiple years from the last year observed to 2019 was reviewed to assess whether habitat conditions have remained stable or if significant changes to the landscape have occurred (Table 4-1).

Table 4-1. Demographic and habitat metrics used to estimate the current population resiliency for 19 extant Ocmulgee skullcap populations. (Number) represents the score assigned for each of the four metrics.

Resiliency	**Demographic Metric**			**Habitat Metric**
Condition Class (Score)	**Number of Individuals**	**Number of occurrences within population**	**Change of number of occurrences within a population**	**Native Herbaceous Ground Cover/Habitat Condition**
High (3)	100 or more	Multiple, widespread clusters of the species	Increasing	None or few invasive exotic plant species; no presence of deer browsing; no significant change of habitat condition
Moderate (2)	60-100	Few, somewhat widespread clusters of the species	Stable	None or few invasive exotic plant species; presence of deer browsing; minor change of habitat condition
Low (1)	40-59 individuals	Couple clusters of the species	Decreasing	Presence of invasive exotic plant species; presence of deer browsing; moderate change of habitat condition
Very Low (0)	Less than 40	Single, isolated site	N/A	Presence of invasive exotic plant species; presence of deer browsing; significant change of habitat condition

Ultimately, an overall score reflecting population resiliency was determined by summing scores assigned in each of four demographic and habitat metrics for each of 19 Ocmulgee skullcap populations, with each metric weighed equally. After calculating the overall resiliency condition score, populations were assigned a resiliency condition class using the scale in Table 4-2.

Table 4-2. Scale used to determine current resiliency condition class for Ocmulgee skullcap populations. Overall scores were summed from demographic and habitat metric scores and were weighted equally.

Resiliency Condition Class	Very Low	Low	Moderate	High
Overall Score	0 to 3	4 to 6	7 to 9	10 to 12

4.3.2 Species Representation and Redundancy

Representation reflects a species' adaptive capacity to respond to changing environmental conditions over time and can be characterized by genetic and ecological diversity within and among populations. Due to the unavailability of information on Ocmulgee skullcap genetic variability, representation was assessed based geographic separation across its range. Ocmulgee skullcap occurs in the Southeastern Plains ecoregion in Georgia and South Carolina and is isolated to the Ocmulgee River and Savannah River watersheds. The Oconee River and Ogeechee River watersheds separate the populations in Ocmulgee and Savannah watersheds, which may influence the genetic makeup, ecological diversity, and/or adaptive capacity of the species. Due to the species' geographic separation between the two watersheds and occurrence within one ecoregion, we assessed representation of Ocmulgee skullcap based on watersheds (Figure 4-3).

To understand the representation of Ocmulgee skullcap, we mapped populations within the watersheds and determined representative units (RUs). We delineated two representative units: the Ocmulgee RU and Savannah RU (Figure 4-3). We characterized representation as the number and distribution of populations within each RU.

Redundancy reflects a species' ability to rebound after a catastrophic event and is measured by the number and distribution of resilient populations, both across the species' range and within representative units. Species that are widely distributed across their historical range are considered less susceptible to extinction and more likely to be viable than species confined to a small portion of their range (Carroll et al. 2009, entire; Redford et al. 2011, entire). For Ocmulgee skullcap, we assessed redundancy by mapping resilient populations within RUs and across the species' entire geographic range (Figure 4-3).

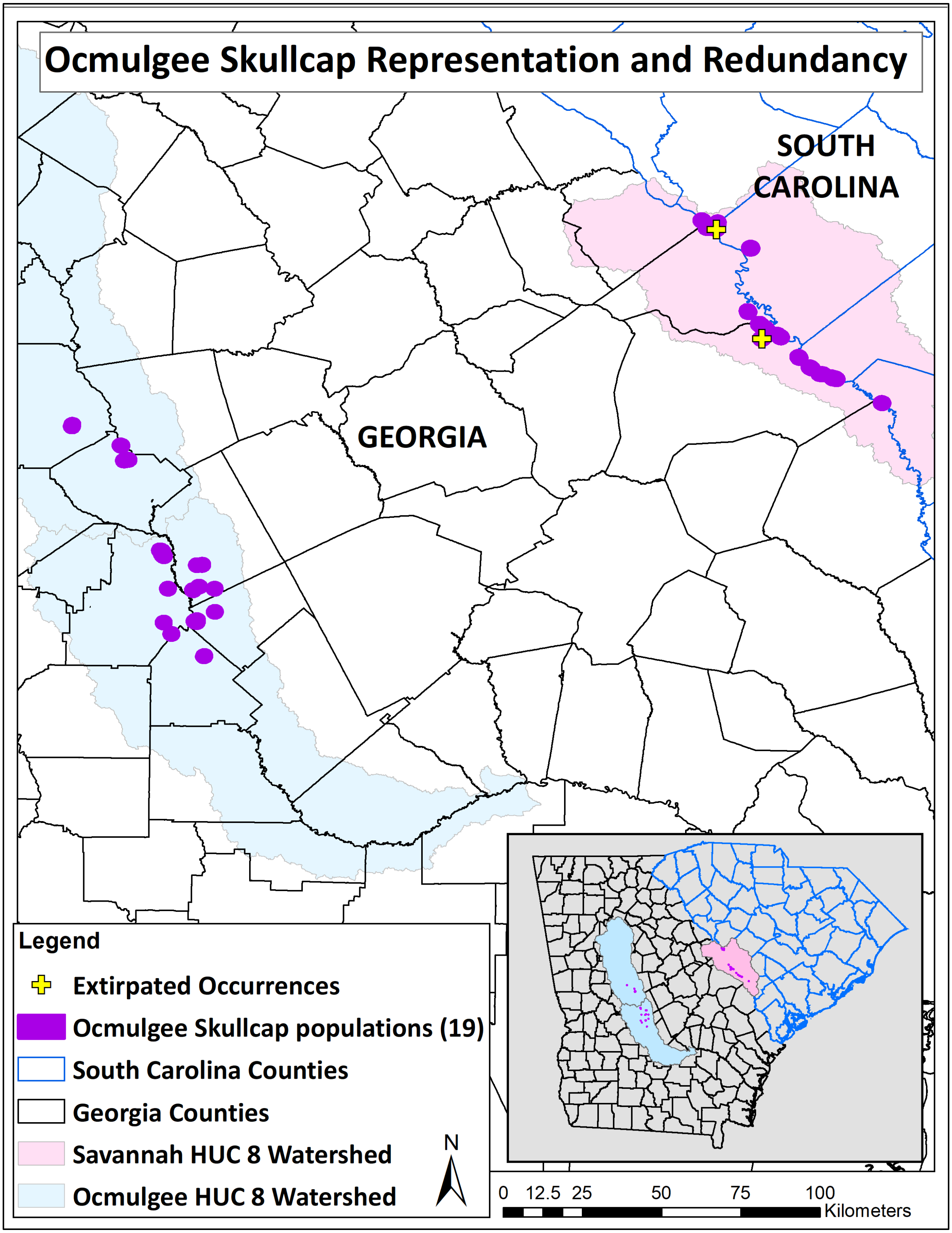

Figure 4-3: Distribution of Ocmulgee skullcap populations in representative units. Two representative units are the Ocmulgee RU (Upper and Lower Ocmulgee HUC 8) shown in blue and the Savannah RU (Middle Savannah HUC 8) shown in pink. The purple circles represent extant populations. Yellow crosses are the presumed extirpated occurrences.

4.4 Current Condition Results

4.4.1 Current Population Resiliency

Approximately 1,200 individuals are estimated to currently occur in the 19 known populations. Two occurrences in two populations are presumed extirpated, and almost all populations show signs of deer herbivory and/or nonnative invasive species (Appendix A). Eight of the 19 populations (42 percent) are potentially protected and/or managed (Federally owned, State owned or privately owned and managed for conservation) (Figure 4-4). Populations on protected lands are considered less at risk from stressors associated with current and future development due to long-term management plans, conservation easements in perpetuity, or other protective mechanism.

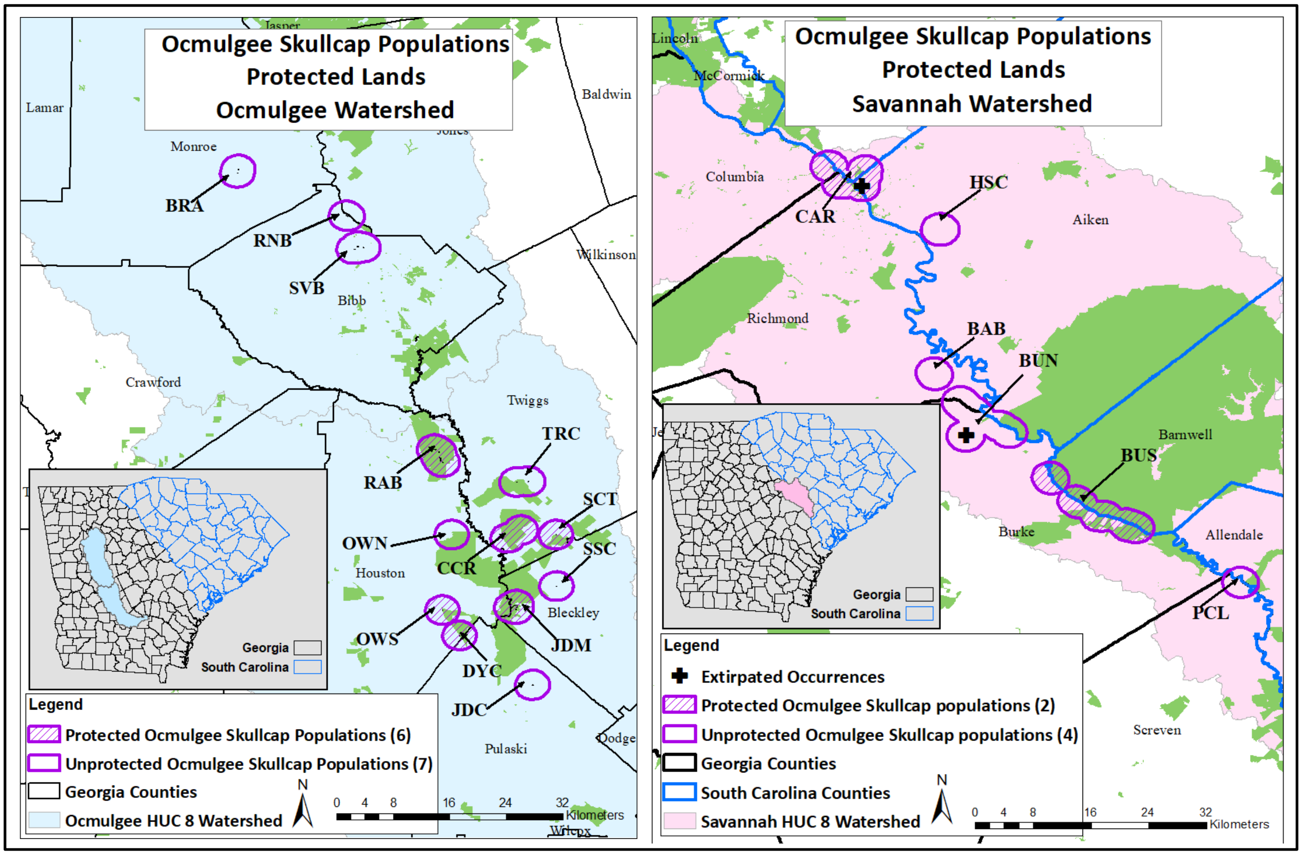

Figure 4-4. Distribution of the 19 Ocmulgee skullcap populations across the range with protected lands shown in green polygons. The purple circles represent the populations. Populations that occur on protected lands are shown with purple hashing. Black crosses are the presumed extirpated occurrences in the Savannah watershed. Ocmulgee populations are shown in the figure on the left and the Savannah populations are shown in the figure on the right.

Of the 19 extant Ocmulgee skullcap populations, only one population (BUS) currently exhibits high resiliency (Table 4-3). This resiliency was largely due to the population size (about 319 individuals), number of occurrences in the population, and minimal deer herbivory and limited presence of nonnative invasive species. The BUS population occurs mostly on the Yuchi Wildlife Management Area where it can be protected and managed. We determined two populations (BUN and JDM) currently exhibit moderate resiliency. The BUN population has several widespread occurrences and over 100 individuals were reported in 1999 from two occurrences (Morris 1999, entire), but the third occurrence in this population is possibly extirpated due to timber harvesting. The BUN population is not protected as it occurs entirely on private lands. Multiple, widespread occurrences and/or patches contribute to the JDM population's moderate level of resiliency. The JDM population also occurs on the Ocmulgee Wildlife Management Area where management of deer and nonnative invasive plants may occur.

Eight populations were estimated to have low resiliency and eight were estimated to have very low resiliency. Six of these 16 populations that were estimated to have low or very low resiliency are located on protected land (Table 4-4). Although the risk of development on protected land is lower, currently there are no known targeted management strategies for the populations occurring on protected land. The CAR population has been estimated to contain a relatively high number of individuals (about 450) and most of the population occurs on protected land (Greystone Preserve in South Carolina). However, one of the occurrences has been extirpated due to deer herbivory and nonnative invasive plant species are a serious threat to the occurrence at Greystone Preserve (Bradley 2019, p.22).

In summary, of the 19 extant Ocmulgee skullcap populations, 1 was assessed to have high resiliency and 2 have moderate resiliency. The other 16 populations exhibit low to very low resiliency. Two occurrences within two different populations along the Savannah River were extirpated due to severe deer herbivory and land conversion.

Table 4.3. Current resiliency of 19 extant Ocmulgee skullcap populations across the species' range. Ocmulgee populations are highlighted in blue and Savannah populations are highlighted in yellow.

Population Name	Population Code	Resiliency Score	Resiliency Class	Protected	Protection Notes
James Dykes Memorial	JDM	7	MODERATE	Yes	Ocmulgee Wildlife Management Area (State Lease)
Robins AFB	RAB	6	LOW	Yes	Robins Air Force Base (Federal)
Savage Branch	SVB	6	LOW	No	NA
Bolingbroke Rest Area	BRA	5	LOW	No	NA
Crooked Creek	CCR	5	LOW	Yes	Ocmulgee Wildlife Management Area (State Lease)
Jordan Creek	JDC	4	LOW	No	NA
Shellstone Creek	SCT	4	LOW	Yes	Ocmulgee Wildlife Management Area (State Lease)
Dry Creek	DYC	3	VERY LOW	Yes	Oaky Woods Wildlife Management Area (State Lease)
Oaky Woods WMA North	OWN	3	VERY LOW	No	Just off northeast corner of Oaky Woods WMA
Oaky Woods WMA South	OWS	3	VERY LOW	Yes	Oaky Woods Wildlife Management Area (State Lease)
River North Bluff	RNB	3	VERY LOW	No	NA
South Shellstone Creek	SSC	3	VERY LOW	No	NA
Tributary to Richland Creek	TRC	3	VERY LOW	No	NA
Burke South	BUS	10	HIGH	Yes	Mostly on Yuchi Wildlife Management Area (State), one occurrence on Plant Vogtle (Georgia Power), one occurrence on other private lands
Burke North	BUN	7	MODERATE	No	NA
Columbia Richmond	CAR	6	LOW	Yes	Greystone and Savannah River Bluffs Heritage Preserves, three occurrences not protected (one on county land)
Barney Bluff	BAB	5	LOW	No	NA
Horse Creek	HSC	3	VERY LOW	No	NA
Prescott Lakes	PCL	3	VERY LOW	No	NA

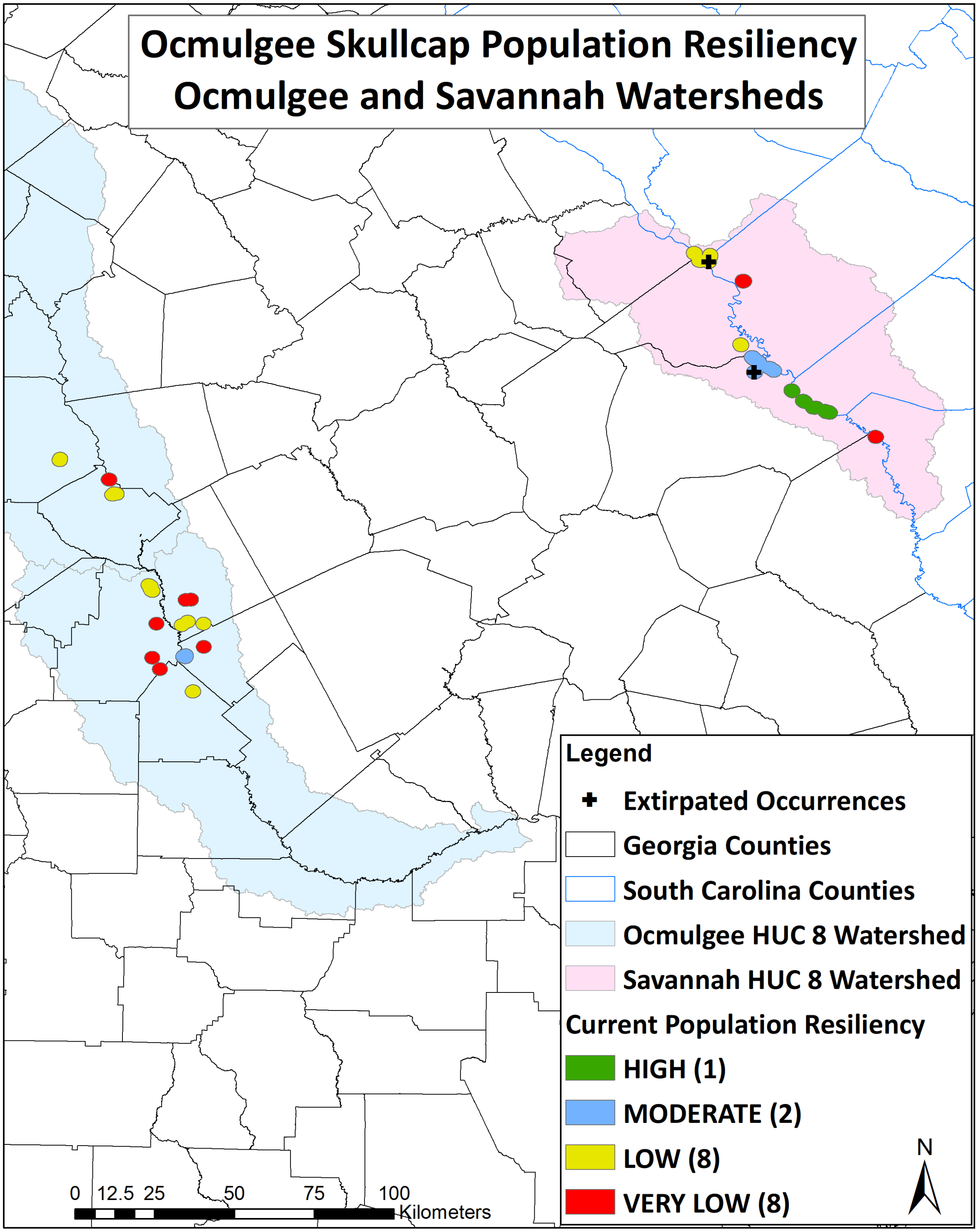

Figure 4-5. Current resiliency of Ocmulgee skullcap current populations in the Ocmulgee and Savannah representative units.

4.4.2 Current Species Representation

To determine the current level of representation for the Ocmulgee skullcap, we considered the number of populations in each RU, the number of RUs or watersheds with species occurrence, and the range of environmental conditions the two RUs represent. At present, the Ocmulgee skullcap is represented by 19 populations with varying levels of resiliency occurring in two non-contiguous watersheds with 13 populations in the Ocmulgee RU and 6 in the Savannah RU (Figure 4-5, 4-6). In the Savannah RU, one occurrence each within the CAR and BUN populations have been extirpated due to severe deer herbivory and land conversion, respectively. Limited connectivity among populations within the RUs reduces the opportunities for genetic exchange. The Ocmulgee skullcap currently occurs in two watersheds in multiple populations with no known population-level extirpations. Therefore, we determined the Ocmulgee skullcap is likely lower than its historical but retains moderate adaptive capacity to adapt to changing environmental conditions.

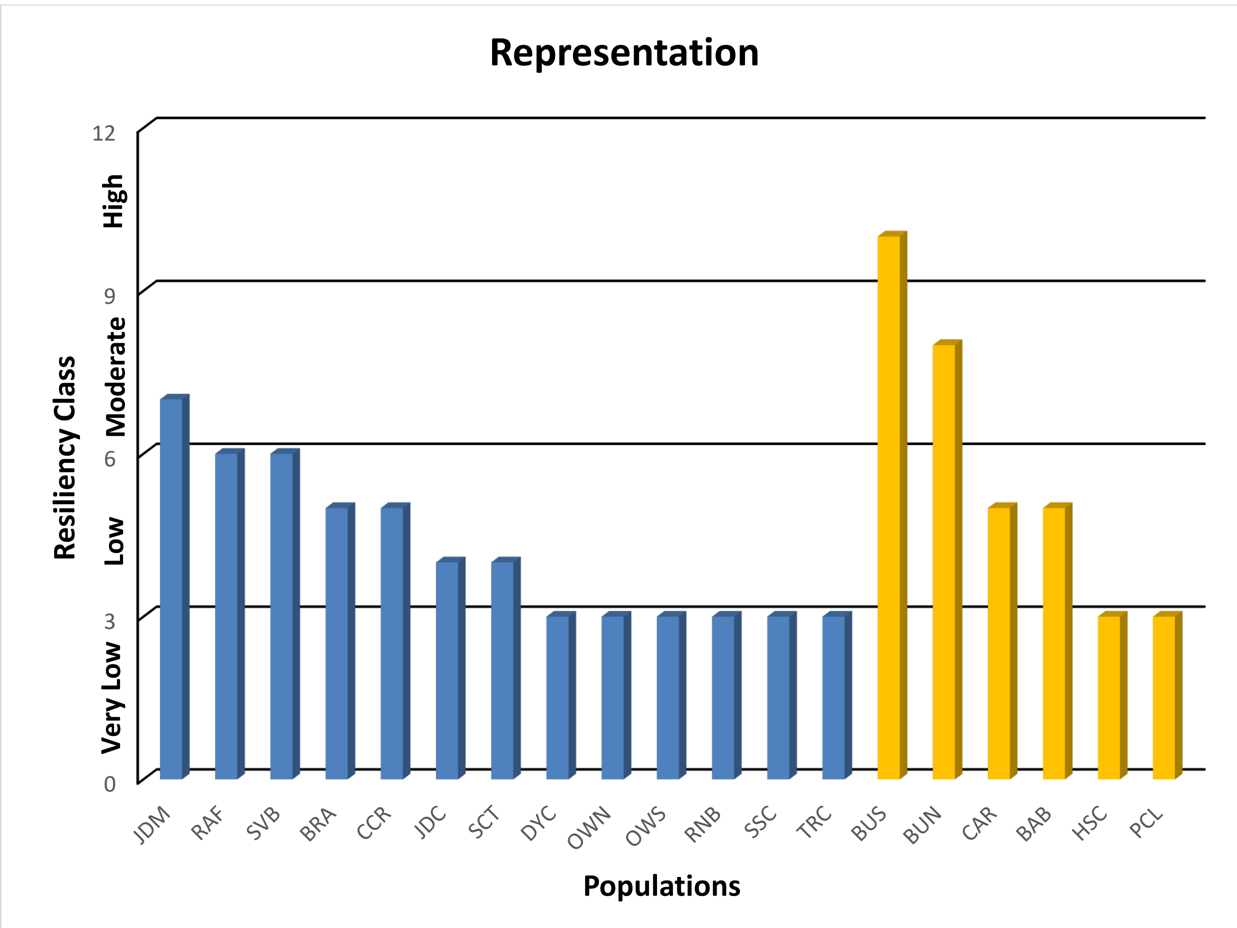

Figure 4-6. Ocmulgee skullcap current population resiliency in each representative unit. Blue bars represent populations in the Ocmulgee RU and yellow bars represent populations in the Savannah RU.

4.4.3 Current Species Redundancy

To assess the current redundancy for the Ocmulgee skullcap, we summarized the resiliency, abundance, and distribution of populations within the two representative units, the Ocmulgee RU and the Savannah RU, and across the range of the species (Table 4-5; Figure 4-5; Figure 4-6). The Ocmulgee RU includes one moderately resilient population, six populations with low resiliency and six populations with very low resiliency. The Savannah RU includes a single highly resilient population, one moderately resilient population, two populations with low resiliency, and two with very low resiliency. In comparison to the Savannah RU, the Ocmulgee RU has a greater number of populations, but they are less resilient. The Savannah RU has higher levels of resiliency, but fewer populations. A more detailed description of the species' condition in each representative unit follows.

Table 4-5. Representative units for Ocmulgee skullcap characterized by the number of populations, and current population resiliency condition classes.

Representative Unit	Number of Populations	High Resiliency	Moderate Resiliency	Low Resiliency	Very Low Resiliency
Ocmulgee	13	0	1	6	6
Savannah	6	1	1	2	2
Rangewide	19	1	2	8	8

Ocmulgee Representative Unit

The Ocmulgee RU contains one population with moderate resiliency (JDM) and 12 populations with low or very low resiliency (Figure 4-7). While the Ocmulgee RU has more known populations compared to the Savannah RU, most populations in the Ocmulgee RU exhibit low to very low resiliency. Therefore, this RU is at a higher risk of extirpation of multiple populations and indicates a potential for loss of adaptive capacity. The 13 populations in the Ocmulgee RU are widely distributed within the occupied portion of the RU, with three populations in the upstream portion of the RU and the remainder of the populations (including the moderately resilient population) are found in the downstream portion of the RU.

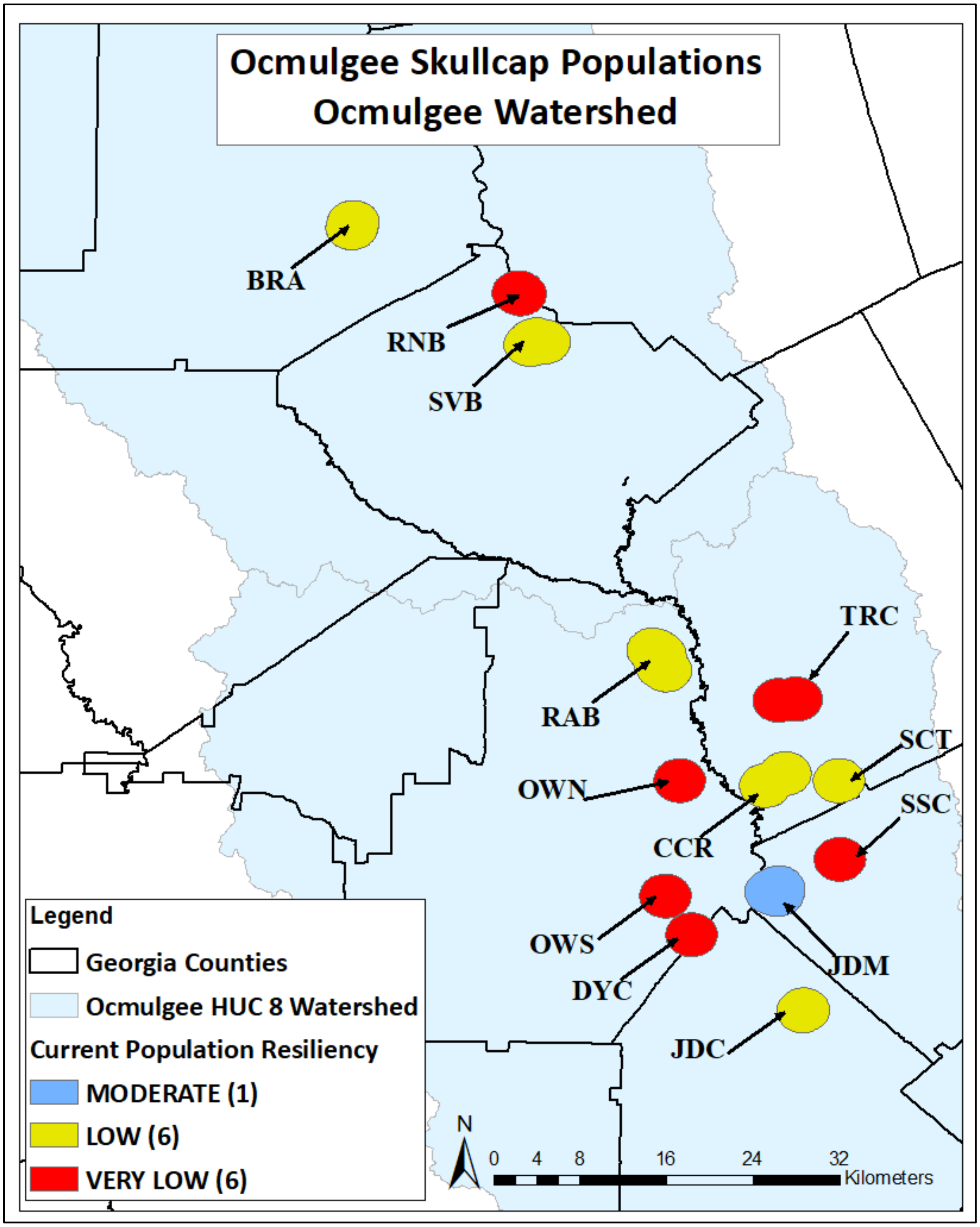

Figure 4-7. Population resiliency and distribution within the Ocmulgee RU.

<u>Savannah Representative Unit</u>

The Savannah RU contains one population with high resiliency (BUS) and one population with moderate resiliency (BUN) (Figure 4-8). The BUS population occurs mostly on the Yuchi Wildlife Management Area with the remaining portions on Georgia Power's Plant Vogtle and other private lands. The six populations in the Savannah RU are distributed roughly equally along the central portion of the RU (generally northwest to southeast). The southernmost (most downstream) population and the two northernmost (most upstream) populations of Ocmulgee skullcap within the Savannah RU have low or very low resiliency. Loss of these populations would reduce the extent of the species' range within this representative unit. Two occurrences in the CAR and BUN populations are considered extirpated.

Figure 4-8. Population resiliency and distribution within the Savannah RU.

Redundancy of resilient populations was determined to be reduced compared with its historical condition due to extirpation of two occurrences. Furthermore, some populations exhibit reduced abundance of individuals over time although we were not able to assess this for all populations due to incomplete data. Multiple resilient populations distributed across the species' historical range make the species more robust and able to withstand a catastrophic event. Populations exhibiting low or very low resiliency are likely not able to withstand a catastrophic event. In the Ocmulgee RU, there is currently only one population with moderate resiliency; therefore, there is limited redundancy in this RU. In addition, connectivity between and among populations is limited; therefore, the species is susceptible to extirpation if a large-scale catastrophic event occurs since recolonization from nearby populations is unlikely. Within the Savannah RU, one high and one moderately resilient population occur; therefore, redundancy is limited in this RU. In summary, there has been limited reduction in Ocmulgee skullcap redundancy as compared with historical condition across the species' range, but the species is still characterized by multiple redundant populations distributed across the species range.

4.5 Current Condition Summary

The current distribution of Ocmulgee skullcap populations represents the historical range of the species within the Ocmulgee and Savannah watersheds. However, the resiliency of the majority (16 of 19) of populations across the range was determined to be low or very low. Only one population within the Ocmulgee RU exhibits moderate resiliency; and two populations within the Savannah RU exhibit moderate or high resiliency. Two occurrences within extant populations in the Savannah RU are presumed extirpated. The Ocmulgee skullcap has generally low resilience to stochastic events at the population level. The Ocmulgee skullcap is found in two non-contiguous RUs (watersheds) in two states; however, most populations within the RUs do not experience connectivity to another population. We determined the Ocmulgee skullcap exhibits moderate representation and the species may currently have reduced adaptive capacity. Ocmulgee skullcap populations are distributed along the Ocmulgee and Savannah rivers across the two RUs where the species occurs. The species-level redundancy was determined to be reduced from historical condition and is characterized by multiple redundant populations. Overall, the Ocmulgee skullcap current condition is characterized by low resilience, moderate representation and reduced redundancy. Additional conservation measures may be needed to improve the long-term viability for this species.

CHAPTER 5. FUTURE CONDITIONS

In the previous chapters, we described the Ocmulgee skullcap's ecological and resource needs (Chapter 2), factors influencing the current and future viability of the species (Chapter 3), and the current condition of the species (Chapter 4). We now consider the species' future conditions by applying the concepts of resiliency, representation, and redundancy to describe the future viability of the Ocmulgee skullcap.

5.1 Introduction to Methods for Assessing Future Condition

We considered the most important factors that may influence the Ocmulgee skullcap when predicting future conditions. Factors included: (1) loss of habitat from development (i.e., urbanization), (2) herbivory from white-tailed deer, and (3) competition from nonnative invasive species. Future fluctuations in precipitation and increased annual average temperatures as a result from climate change may also impact the species, but these were not included in our future predictions due to uncertainty surrounding the effects to the species (see section 3.5 Climate Change).

The main factors influencing Ocmulgee skullcap are habitat based. Therefore, we conducted a spatial analysis to project the future probability of development, and incorporated predictions regarding Ocmulgee skullcap's response to that development, under three plausible future scenarios. Based on the average lifespan of the species (5–8 years), confidence in projections and models of factors influencing the species' viability, and certainty in predictions of the species' response to those factors, we chose a predictive time horizon of 2040 and 2060. By using 20-year time steps for future predictions, we represented a minimum of three generations to account for normal variation in plant reproduction and annual variation in climate conditions. The time steps begin in 2018, as this was the end of our current condition timeframe.

We used two models to predict the probable future conditions for this species: 1) a habitat suitability model, and 2) an urbanization (SLEUTH) model. First, we used a habitat suitability model to predict the location of potential suitable habitat for Ocmulgee skullcap (Ramirez-Reyes et al. 2020, entire). Second, we used the SLEUTH model (Terando et al. 2014, entire) to predict the potential impact of future development on potentially suitable habitat. We analyzed the impact from development on suitable habitat by using the inputs from the SLEUTH model and habitat suitability model. Then, we calculated the total area overlapped within each population boundary, (i.e., the total area potentially lost from encroaching development). In populations where the entire area of the known occurrence falls within the boundaries of protected lands, we inferred that development would have a neutral impact regarding Ocmulgee skullcap's resiliency.

5.2 Projections and Modeling

5.2.1 Habitat Suitability Model

A fine-scale habitat suitability model was used to predict the location of potential suitable habitat for Ocmulgee skullcap based on the environmental conditions associated with known extant populations (Ramirez-Reyes et al. 2020, entire).

Data Used

To model habitat suitability for Ocmulgee skullcap, two sets of information were used: a) the geographic coordinates of known extant locations of the species; and b) environmental information that is hypothesized to influence the species. This data was characterized in the form of digital environmental maps (Table 5-1).

The location of extant populations was used as a measure of presence for the Ocmulgee skullcap. The Ocmulgee skullcap's needs (sunlight, moist soil, calcium-rich soil, pollination, etc.) to grow, reproduce, and survive were considered and incorporated as environmental variables (e.g., elevation, precipitation, and temperature) that could influence the presence of the species. In the modeling, 14 variables were included and not correlated to each other (Table 5-1).

Table 5-1. Environmental variables used in habitat suitability modeling for Ocmulgee skullcap (Ramirez-Reyes et al. 2020, entire).

Variable	Description	Sources
LST	Surface temperature (°C)	Landsat
DEM	Digital elevation model (m)	STRM
Burned_area		MODIS, 500m
Land cover	Ecological system and landcover map, 9 classes	ESLF-NatureServe
Soil type	72 classes	NRCS soil data
Slope/Eastness/Northness	Derived from DEM	STRM_DEM
NPP/GPP	Net primary Production/Gross Primary Production	Landsat
NDV/EVI	Vegetation Indices	Landsat
VCF	The Landsat Vegetation Continuous Fields (VCF) tree cover	Landsat
Bio5	Max Temperature of Warmest Month	WorldClim
Bio6	Max Temperature of Coldest Month	WorldClim
Bio10	Mean Temperature of Warmest Quarter	WorldClim
Bio11	Mean Temperature of Coldest Quarter	WorldClim
Bio12	Annual Precipitation	WorldClim

Habitat Modelling Approach

The species' presence and environmental data were used in three common algorithms to model habitat suitability: generalized additive model (GAM), generalized boosted model (GBM), and maximum entropy (MAXENT). Each of these approaches produced a habitat suitability score for every pixel in the map. To verify the accuracy of these predictions, the commonly used area under the receiver operating characteristic curve (AUC) was calculated. Because each of these three approaches has different assumptions and strengths, and therefore a different AUC, a model ensemble approach was used to minimize uncertainties associated with each individual model. The ensemble model was built by averaging the results of each of the three approaches weighted by their performance. In this way, an approach that performed well will have higher weight in the ensemble. The final model ensemble produced a habitat suitability map for the species containing a constructed scale ranging from 0 (lowest suitability) to 1 (highest suitability).

5.2.2 Development Modelling

We used the SLEUTH development projections (Terando et al. 2014, entire) for the southeastern United States for the years 2040 and 2060. This model predicts the probability of development occurring in a given area, at predetermined time steps (circa 2009 and over 10-year increments to the year 2100) into the future. Using the SLEUTH model, we calculated the amount of suitable habitat projected to be lost to development. In some cases, the SLEUTH model projected habitat on protected lands to become developed. In these situations, we inferred that protected habitat would not be developed and maintained the total suitable habitat within protected lands. We considered two levels of possible development (urbanization probabilities), Low and High Development, at years 2040 and 2060:

(1) Under Low Development probability, we limited the SLEUTH model to include areas where development had a 90 to 100% probability to occur.

(2) Under High Development probability, we allowed the SLEUTH model to include areas where development had a 10 to 100% (all probabilities of development) probability to occur.

The equation to calculate this future suitable habitat is:

Future Suitable Habitat = Projected Suitable Habitat * (1-Probability of Development)

We also calculated the percent habitat loss with the equation:

Percent Habitat Loss = (1-(Projected Suitable Habitat / Current Suitable Habitat))

We restricted the results to any area within the 2 km (1.24 mi) population boundary. Due to the soil requirements of the species and its preference to steep slopes and bluffs, we inferred the 2 km (1.24 mi) buffer adequately resembles the “on the ground” effect of development (i.e., the effects of development will reach 2 km (1.24 mi). Simple calculations could be made by comparing the areal extent of current suitable habitat within each 2 km (1.24 mi) buffer to those in the future following projected development. The habitat model did not include three populations (BRA, JDC, and PCL) because these populations are located on the edge of the range for Ocmulgee skullcap, therefore habitat was not predicted for these populations at the time of modelling. To estimate impacts of development on habitat for these three populations, we calculated the percent of the total population area projected to be lost to development.

5.2.3 Analysis Results

Projected suitable habitat losses for the populations ranged from 0 to 88% at 2040 and 0 to 90% 2060 (Table 5-2). For the 13 populations within the Ocmulgee RU, projected habitat losses were 0 to 90% at 2040 and 2060. In the 6 populations in the Savannah RU, projected habitat losses were 0 to 41% at 2040 and 0 to 64% at 2060.

We then described the degree of projected suitable habitat loss for each population in terms of three categories of risk of development – Low, Moderate, or High (Table 5-2):

(1) Low Development Risk : 0–33% of suitable habitat loss
(2) Moderate Development Risk : 34–66% of suitable habitat loss
(3) High Development Risk : 67–100% of suitable habitat loss

Table 5-2. Percent suitable habitat loss by population in years 2040 and 2060 for Low and High Development (Dev) probabilities from the SLEUTH model and assigned Development Risk Class. Blue represents the Ocmulgee RU and yellow represents the Savannah RU. Populations with (*) are those that we assessed amount of population area lost to development because they were not included in the habitat model. Details of the development analysis can be found in Appendix B.

Development Risk Class (Low=0-33%, Moderate=34-66%, High=67-100%)								
	% Habitat Loss		% Habitat Loss		Development Risk Class			
Population Code	2040 Low Dev	2040 High Dev	2060 Low Dev	2060 High Dev	2040 Low Dev	2060 Low Dev	2040 High Dev	2060 High Dev
BRA*	0%	0%	0%	0%	LOW	LOW	LOW	LOW
SSC	0%	0%	0%	0%	LOW	LOW	LOW	LOW
TRC	0%	0%	0%	0%	LOW	LOW	LOW	LOW
JDM	0%	0%	0%	0%	LOW	LOW	LOW	LOW
SCT	0%	1%	0%	4%	LOW	LOW	LOW	LOW
JDC*	0%	0%	0%	8%	LOW	LOW	LOW	LOW
CCR	1%	1%	1%	1%	LOW	LOW	LOW	LOW
RAB	2%	2%	2%	2%	LOW	LOW	LOW	LOW
OWN	4%	5%	4%	7%	LOW	LOW	LOW	LOW
DYC	29%	42%	47%	50%	LOW	MODERATE	MODERATE	MODERATE
OWS	31%	50%	53%	64%	LOW	MODERATE	MODERATE	MODERATE
RNB	50%	59%	51%	59%	MODERATE	MODERATE	MODERATE	MODERATE
SVB	88%	90%	89%	90%	HIGH	HIGH	HIGH	HIGH
BUN	0%	0%	0%	0%	LOW	LOW	LOW	LOW
PCL*	0%	0%	0%	0%	LOW	LOW	LOW	LOW
BUS	4%	10%	12%	20%	LOW	LOW	LOW	LOW
HSC	13%	37%	35%	52%	LOW	MODERATE	MODERATE	MODERATE
CAR	29%	36%	36%	42%	LOW	MODERATE	MODERATE	MODERATE
BAB	41%	54%	54%	64%	MODERATE	MODERATE	MODERATE	MODERATE

After reviewing the projected suitable habit loss results for the Low and High Development models, we selected the Low Development model for inclusion in our future condition scenarios because there was no difference in the Development Risk Class assigned among the 2040 High, 2060 Low and 2060 High development probabilities (Table 5-2). Therefore, the predicted development risk class for the low development model in 2060 also represents the change expected in the low development and high development models in 2060.

Using the predicted future development risk, we developed a rule set to determine the change in resiliency class of Ocmulgee skullcap populations from current to future conditions based on risk of development at 2040 and 2060 using the Low Development probability SLEUTH model. Each Ocmulgee skullcap's future population resiliency was predicted as follows: (1) *High Development Risk* resulted in a significant loss of resiliency and a reduction from current condition by two resiliency classes (-2), (2) *Moderate Development Risk* resulted a loss of resiliency with a reduction from current condition by one resiliency class (-1), and (3) *Low Development Risk* resulted in a no change from current to future resiliency (0).

5.3 Incorporating Management into the Future Scenarios

We developed three plausible scenarios to assess the future viability of Ocmulgee skullcap populations. All three scenarios predicted future conditions under varying levels of management, and we predicted how those scenarios contribute to future populations' resiliency, representation, and redundancy.

Scenario 1 – Decrease in Management and Conservation

Under Scenario 1, we considered a future where the existing level of habitat management (nonnative invasive species control, white-tailed deer hunting) decreases over time; there are no additional properties protected where the species occurs and the current amount of protected lands will remain protected through time; and there is no augmentation and/or reintroduction of populations. This scenario is plausible since deer harvest typically decreases in proximity to urbanization with few cities in the species range allowing urban deer hunts (and harvest numbers are low in those that do) (Georgia Urban Deer Management Plan (2015–2024). Land managers of protected lands described a decrease number of potential burn days in the recent past and an expectation that those declines would continue or increase due to climate change. A reduced ability to conduct prescribed fires on protected lands in proximity to urban areas (Columbia/Richmond population) due to safety concerns was also described by land managers. Because nonnative invasive species would not be treated and white-tailed deer populations would not be hunted, we would likely see an increase in stressors that would reduce the available resources for Ocmulgee skullcap. As a result, population resiliency would decrease due to impact of nonnative invasive species and deer herbivory (Table 5-4).

Scenario 2 - Status Quo Management

Under Scenario 2, we considered a future where the existing level of habitat management (nonnative invasive species control, white-tailed deer hunting) remains constant over time; there are no additional properties protected where the species exists and the current amount of protected lands will remain protected through time; propagation and seed storage efforts remain intact but no populations are augmented or reintroduced in the historical range. As a result, management will continue to affect population resiliency in the same manner and to the same extent that it does now (Table 5-4).

Scenario 3- Increase in Management and Conservation

Under Scenario 3, we considered a future where additional management efforts are focused on improving habitat suitability for the Ocmulgee skullcap. We anticipate an increase in removal nonnative invasive species; increased white-tailed deer hunting quotas; additional properties are predicted to be protected where populations and/or suitable habitat are present; and populations are augmented and/or reintroduced on protected lands. The effects of increased management create a net conservation gain to buffer the effects of development. As a result, population resiliency increases regardless of development (Table 5-4).

Summary of Scenarios

Three future scenarios with varying levels of management and conservation efforts were considered: (1) decreased management and conservation, (2) status quo, and (3) increased management and conservation. Using the low probability development SLEUTH model, three categories of development risk were constructed based on the percent of habitat lost for each population: (1) High, (2) Moderate, and (3) Low (Table 5-2). Then, we constructed a rule set to determine the change in resiliency of Ocmulgee skullcap populations from current to future conditions based on the interaction between risk of development and management for the three scenarios at time steps, year 2040 and 2060 (Table 5-3). Each of the predicted scenarios are additive. For example, a population with a high development risk factor (decrease of -1) may also be subject to decreased management and conservation actions in scenario 1 (decrease of -2) due to increased development, leading to an overall decrease of three resiliency classes for the affected population (Table 5-4).

Table 5-3. Model to estimate change in future resiliency in 2040 and 2060 for each Ocmulgee skullcap population. Model inputs include current population resiliency plus the Development (Dev) Risk Factor (from the Low Development SLEUTH model) and three Management Scenarios described in Sections 5.2 and 5.3. Numbers in parentheses indicate change in resiliency classes (0= no change, +1 increase or -1 decrease by one resiliency class, or -2 decrease by two resiliency classes). Development risk factors in **bold** indicate change in the development risk factor between 2040 and 2060.

Population Code	Current Resiliency	2040 Dev Risk Factor	2060 Dev Risk Factor	Management Scenario		
		Change in Resiliency Class in Parentheses				
JDM	MODERATE	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
BRA	LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
CCR	LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
JDC	LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
RAB	LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
SCT	LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
SVB	LOW	HIGH (-2)	HIGH (-2)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
DYC	VERY LOW	**LOW (0)**	**MODERATE (-1)**	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
OWN	VERY LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
OWS	VERY LOW	**LOW (0)**	**MODERATE (-1)**	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
RNB	VERY LOW	MODERATE (-1)	MODERATE (-1)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
SSC	VERY LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
TRC	VERY LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
BUS	HIGH	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
BUN	MODERATE	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
BAB	LOW	MODERATE (-1)	MODERATE (-1)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
CAR	LOW	**LOW (0)**	**MODERATE (-1)**	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
HSC	VERY LOW	**LOW (0)**	**MODERATE (-1)**	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
PCL	VERY LOW	LOW (0)	LOW (0)	DECREASE (-1)	STATUS QUO (0)	INCREASE (+1)
NOTE: The development factor for each population was determined prior to management scenarios. Then, future population resiliency was predicted using three management scenarios.						
MODEL: Current Resiliency + Development Factor + Management Scenario = Future Population Resiliency **EXAMPLE: MODERATE + MODERATE (-1) + DECREASE (-1) = VERY LOW**						

Table 5-4: Change in resiliency class based on interaction between predicted risk of development and management for three plausible future management scenarios to determine change (decrease, stable or increase) in future resiliency classes of Ocmulgee skullcap populations.

Development Risk	Management Scenarios		
	Decrease in Management and Conservation	Status Quo Management for Stability	Increase in Management and Conservation
Low	-1	0	+1
Moderate	-2	-1	+1
High	-3	-2	+1

5.4 Future Condition Results

5.4.1 Future Condition - Resiliency

We predicted the future resiliency of Ocmulgee skullcap populations using the methods described above. Future predictions take into account the impact from future development and the response of the species to the three management scenarios at the time steps of 2040 and 2060 (Table 5-6; Figure 5-1). The current resiliency category is shown for each population and the predicted resiliency in 2040 and 2060 under each of the three future scenarios assessed: Scenario 1-decreased management and conservation efforts, scenario 2- status quo management actions, and scenario 3- increased management and conservation efforts (Table 5-5). Table 5-6 provides the number of the 19 extant populations in each resiliency category and extirpated populations at 2040 and 2060 under each future scenario. Populations are predicted to be extirpated in all scenarios at both time steps; the number of extirpated populations is greatest in scenario 1 (decreased management) with 11 predicted extirpations and slightly less at 2040 under the same scenario with 10 populations extirpated. The information in Table 5-6 is presented in a graphic format in Figure 5-1 with resiliency categories (including extirpated) shown in colors corresponding to those in Figure 4-8 and Tables 5-5 and 5-6.

Table 5-5. Future resiliency of 19 Ocmulgee skullcap populations with future development risk and under three future management scenarios at 2040 and 2060. Population resiliency results that are in **<u>bold and underlined</u>** are those populations where resiliency decreased between 2040 and 2060 due to increased development risk in 2060. All other population resiliency was the same between 2040 and 2060.

Population Code	Current Resiliency	FUTURE RESILIENCY WITH MANAGEMENT SCENARIO					
		YEAR 2040 DEVELOPMENT RISK			YEAR 2060 DEVELOPMENT RISK		
		DECREASE	STATUS QUO	INCREASE	DECREASE	STATUS QUO	INCREASE
Ocmulgee RU							
JDM	MODERATE	LOW	MODERATE	HIGH	LOW	MODERATE	HIGH
BRA	LOW	VERY LOW	LOW	MODERATE	VERY LOW	LOW	MODERATE
CCR	LOW	VERY LOW	LOW	MODERATE	VERY LOW	LOW	MODERATE
JDC	LOW	VERY LOW	LOW	MODERATE	VERY LOW	LOW	MODERATE
RAB	LOW	VERY LOW	LOW	MODERATE	VERY LOW	LOW	MODERATE
SCT	LOW	VERY LOW	LOW	MODERATE	VERY LOW	LOW	MODERATE
SVB	LOW	EXTIRPATED	EXTIRPATED	EXTIRPATED	EXTIRPATED	EXTIRPATED	EXTIRPATED
<u>DYC</u>	VERY LOW	EXTIRPATED	EXTIRPATED	LOW	EXTIRPATED	EXTIRPATED	**<u>EXTIRPATED</u>**
OWN	VERY LOW	EXTIRPATED	EXTIRPATED	MODERATE	EXTIRPATED	EXTIRPATED	MODERATE
<u>OWS</u>	VERY LOW	EXTIRPATED	EXTIRPATED	LOW	EXTIRPATED	EXTIRPATED	**<u>EXTIRPATED</u>**
RNB	VERY LOW	EXTIRPATED	EXTIRPATED	VERY LOW	EXTIRPATED	EXTIRPATED	VERY LOW
SSC	VERY LOW	EXTIRPATED	VERY LOW	LOW	EXTIRPATED	VERY LOW	LOW
TRC	VERY LOW	EXTIRPATED	VERY LOW	LOW	EXTIRPATED	VERY LOW	LOW
Savannah RU							
BUS	HIGH	MODERATE	HIGH	HIGH	MODERATE	HIGH	HIGH
BUN	MODERATE	LOW	MODERATE	HIGH	LOW	MODERATE	HIGH
BAB	LOW	EXTIRPATED	VERY LOW	LOW	EXTIRPATED	VERY LOW	LOW
<u>CAR</u>	LOW	VERY LOW	LOW	MODERATE	**<u>EXTIRPATED</u>**	**<u>VERY LOW</u>**	**<u>LOW</u>**
<u>HSC</u>	VERY LOW	EXTIRPATED	VERY LOW	LOW	EXTIRPATED	**<u>EXTIRPATED</u>**	**<u>VERY LOW</u>**
PCL	VERY LOW	EXTIRPATED	VERY LOW	LOW	EXTIRPATED	VERY LOW	LOW

Table 5-6. Predicted Ocmulgee skullcap population resiliency for the Ocmulgee and Savannah RUs under three scenarios at 2040 and 2060. Scenario 1 is decreased management; Scenario 2 is status quo management; and Scenario 3 is increased management.

Representative Unit		Resiliency Condition Category					Total Extant Populations
Ocmulgee RU		**High**	**Moderate**	**Low**	**Very Low**	**Extirpated**	**Ocmulgee RU**
Current Resiliency		0	1	6	6	0	13
2040	Scenario 1	0	0	1	5	7	6
	Scenario 2	0	1	5	2	5	8
	Scenario 3	1	6	4	1	1	12
2060	Scenario 1	0	0	1	5	7	6
	Scenario 2	0	1	5	2	5	8
	Scenario 3	1	6	2	1	3	10
Savannah RU		**High**	**Moderate**	**Low**	**Very Low**	**Extirpated**	**Savannah RU**
Current Resiliency		1	1	2	2	0	6
2040	Scenario 1	0	1	1	1	3	3
	Scenario 2	1	1	1	3	0	6
	Scenario 3	2	1	3	0	0	6
2060	Scenario 1	0	1	1	0	4	2
	Scenario 2	1	1	0	3	1	5
	Scenario 3	2	0	3	1	0	6

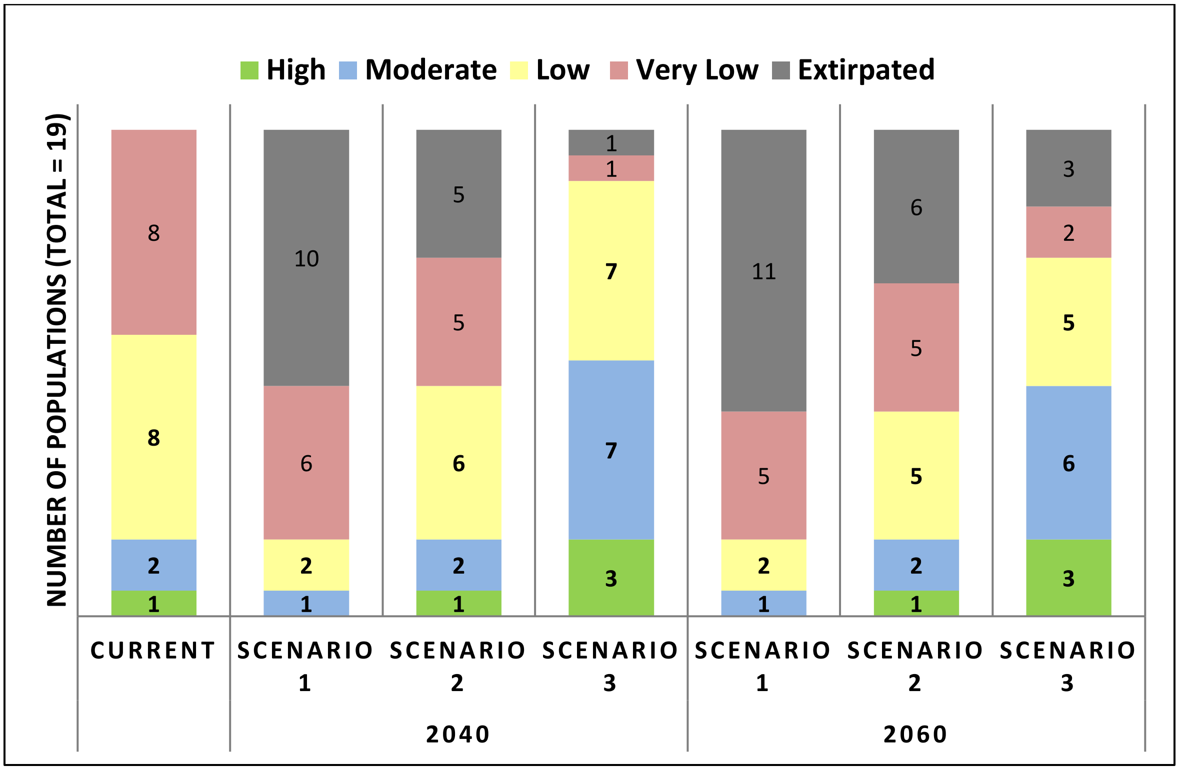

Figure 5-1. Future resiliency for 19 Ocmulgee skullcap populations at 2040 and 2060 under three future scenarios. Scenario 1 is decreased management; Scenario 2 is status quo management; and Scenario 3 is increased management. Current population resiliency is shown for comparison.

Scenario 1 – Decrease in Management and Conservation

Under Scenario 1, due to the decrease in management and conservation, the projected risk of development had a strong impact on population resiliency such that all populations were predicted to experience some level of decline. By 2040, the projected change in resiliency results in 10 populations becoming extirpated (Table 5-5 and 5-6; Figure 5-1), and this predicted loss increases to 11 extirpated populations by 2060. Of the remaining extant populations (7 and 8, respectively), only one population is expected to have moderate resiliency (BUS) (no highly resilient populations, and the rest are predicted to have low to very low resiliency. Decreases in population resiliency are attributed to the effects of development (e.g., habitat loss, runoff) and decreased management (increase in deer herbivory and competition with native and nonnative plants) in the future. All populations across the range will likely be impacted by increasing deer populations due to decreased hunting, which results in higher amounts of foraging (i.e. herbivory). Furthermore, under this scenario, there is a decrease in management for nonnative invasive species that leads to increased competition with Ocmulgee skullcap. The population extirpations and reduced resiliency are distributed across both RUs such that one RU is not disproportionately affected by the predicted changes in condition.

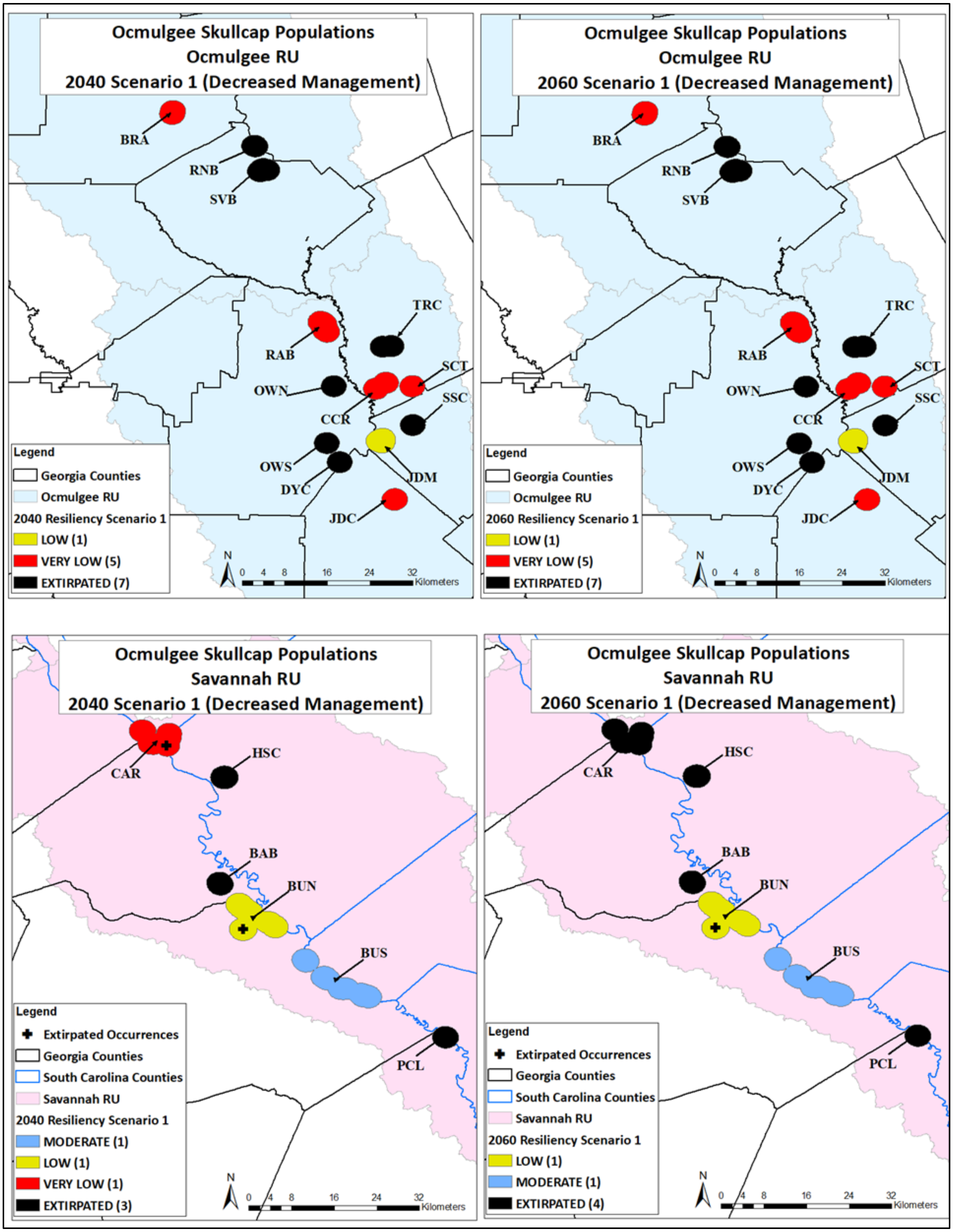

Figure 5-2: Future population resilience at 2040 and 2060 under Scenario 1 (decreased management and conservation) within the Ocmulgee and Savannah RUs.

Scenario 2 – Status Quo

Under Scenario 2, maintaining the current level of management and conservation in an effort to buffer the impacts from development results in the extirpation of five and six populations at 2040 and 2060, respectively (Table 5-5 and 5-6; Figure 5-1). Of the 14 and 13 extant populations, one population (BUS) is predicted to continue to have high resiliency and two populations (JDM and BUN) are predicted to have moderate resiliency at 2040 and 2060, respectively. Ten to eleven populations will have a low or very low resiliency at 2040 and 2060. Again, both RUs are affected similarly by the change in population resiliency.

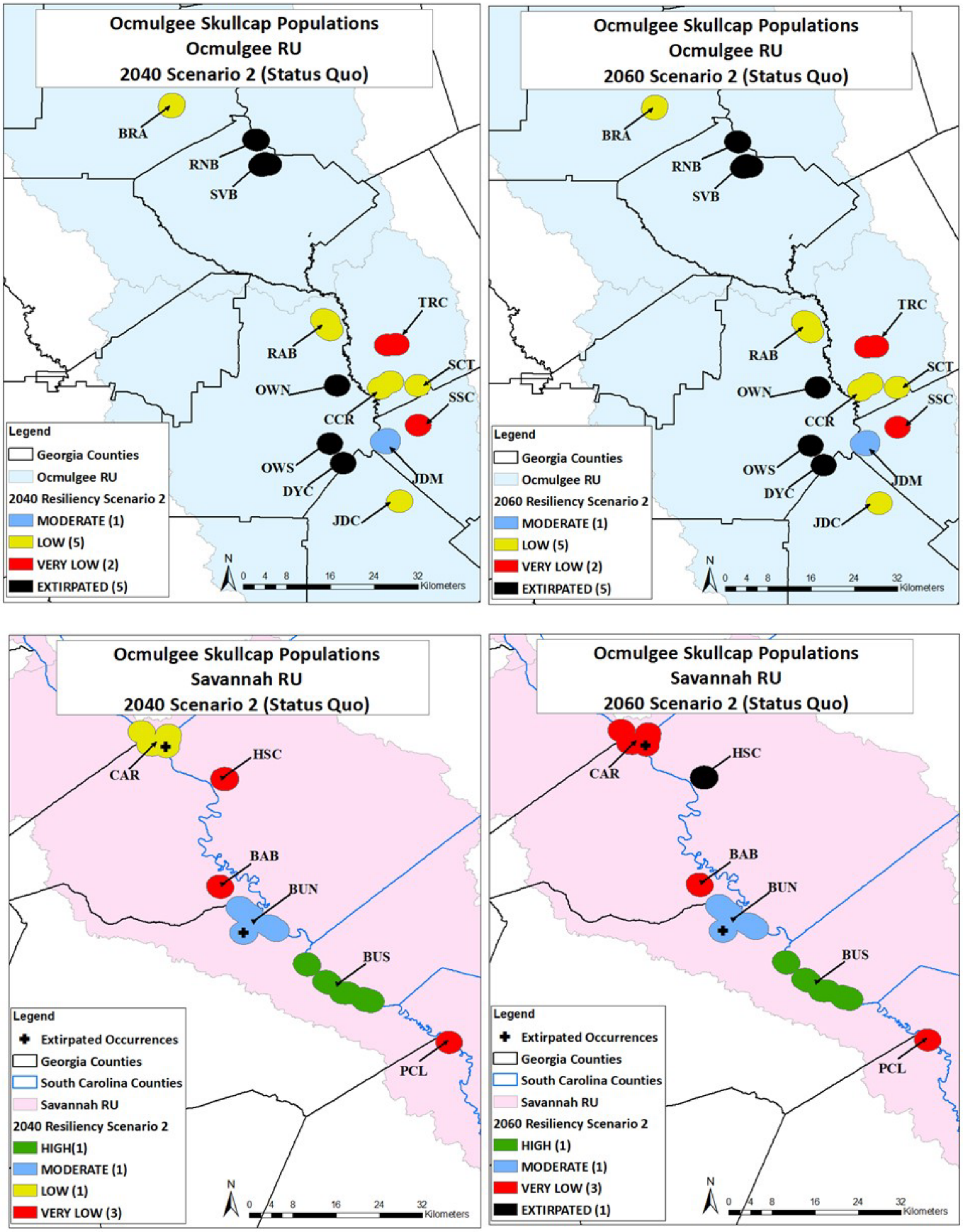

Figure 5-3. Future population resilience for years 2040 and 2060 under Scenario 2 (status quo) within the Ocmulgee and Savannah RUs populations.

Scenario 3 – Increase in Management and Conservation

Under Scenario 3, by increasing land protection and management practices to improve habitat conditions, and augmenting or reintroducing populations, the resiliency of Ocmulgee skullcap is predicted to increase across its range. One and three extirpations are predicted at 2040 or 2060, respectively, due to stressors caused by development (Table 5-5 and 5-6; Figure 5-1). Of the 18 populations predicted to be extant in 2040, three are expected to exhibit high resiliency (JDM, BUS, BUN) and seven are expected to exhibit moderate resiliency. Of the 16 populations predicted to be extant in 2060, three are expected to exhibit high resiliency and six are expected to exhibit moderate resiliency. Seven populations in 2040 and eight populations in 2060 are predicted to have low or very low resiliency. With the exception of the number of moderately resilient populations remaining at 2040, populations in the two RUs are similarly affected by the changes in resiliency condition in Scenario 3.

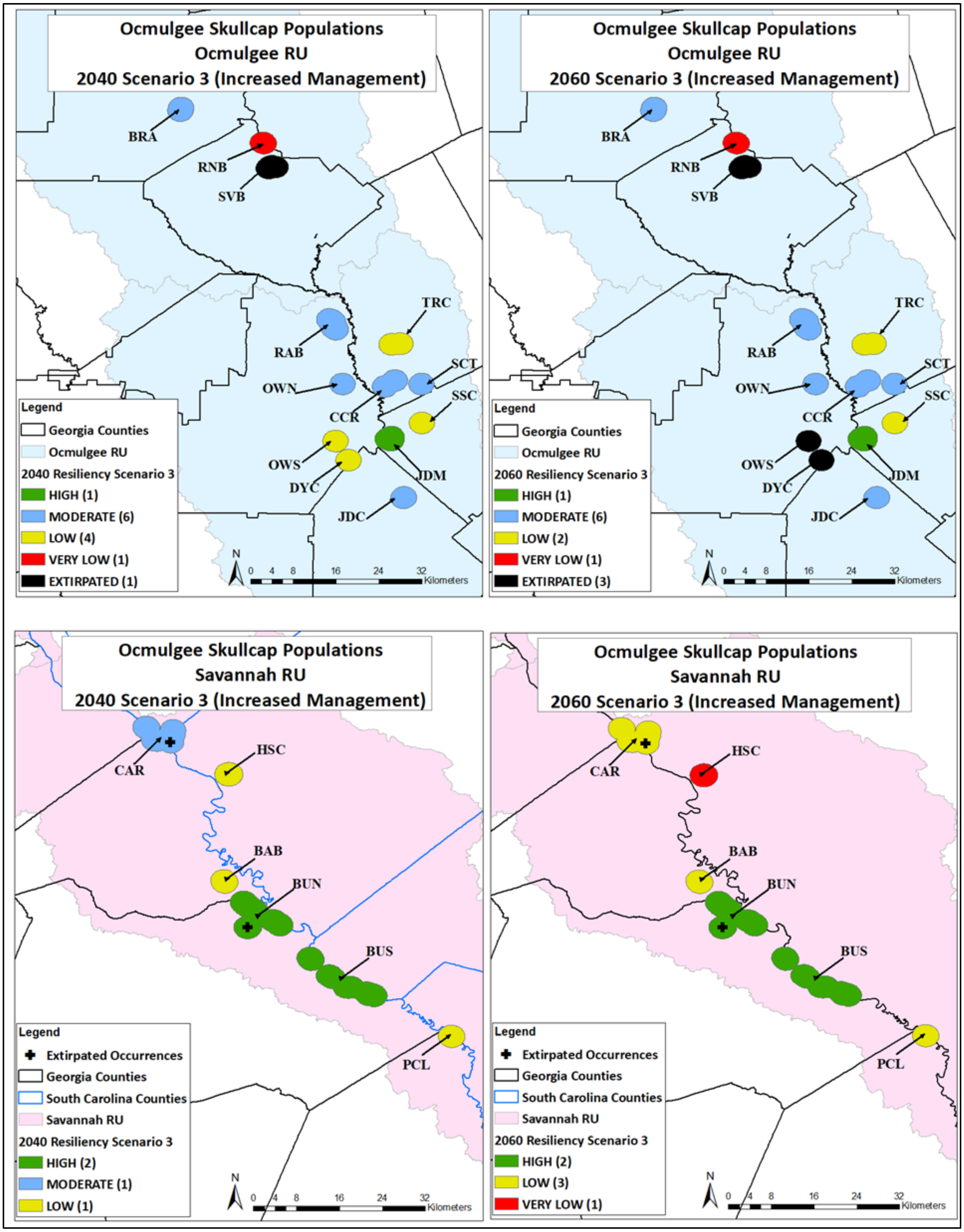

Figure 5-4. Future population resilience for years 2040 and 2060 under Scenario 3 (increased management) within the Ocmulgee and Savannah RUs.

Summary of Resiliency under Future Scenarios
In summary, if management and conservation efforts are decreased in the future (Scenario 1) only one moderately resilient population is predicted to remain (no highly resilient populations), In addition, 10 to 11 populations (53 to 58%) are predicted to become extirpated at 2040 and 2060, and eight (2040) to seven (2060) populations with low or very low resiliency remain. If the current implementation of management and conservation efforts continue (Scenario 2), the projected change in resiliency results in the extirpation of five (2040) or six (2060) Ocmulgee skullcap populations (26 to 32% reduction) at 2040 and 2060 due to development. Across the range, approximately 70 to 85% (10 and 11) of the remaining extant populations (14 and 13) are predicted to have low or very low resiliency at 2040 and 2060, respectively. In contrast, if management efforts increase across the species' range (Scenario 3), the number of extant populations is predicted to only decrease by one to three due to stressors related to development and resiliency is predicted to increase for the majority of the populations.

5.4.2 Future Species Representation

To predict species' representation under plausible future scenarios, we characterized the number and distribution of populations in the Ocmulgee and Savannah Representative Units and throughout the species' range under the three future scenarios described in 5.2 Projection sand Modeling and 5.3 Incorporating Management into the Future Scenarios.

Scenario 1
Under Scenario 1 (decreased management and conservation), extirpation of populations and subsequent reduced distribution of populations is predicted; therefore, future representation is predicted to decline for the Ocmulgee skullcap (Table 5-6, Figure 5-2). The Ocmulgee skullcap is currently represented by 19 populations in two representative units (watersheds) in two states.

Within the Ocmulgee RU, seven populations are predicted to be extirpated at 2040 and 2060. The extirpated populations are distributed throughout the RU with no particular area of concentration of population loss. In the Savannah RU, three populations are predicted to be extirpated in 2040, with an additional population extirpated in 2060. The extirpations under this scenario in the Savannah RU in 2060 occur in the most upstream and the most downstream portions of the current range. Extirpation of these populations will lead to a contraction of the range in the Savannah RU with the two remaining populations occupying the central portion of the RU (Figure 5-2). In addition, remaining populations will be more distant with reduced connectivity, further limiting the potential for genetic exchange.

At 2040 and 2060, Ocmulgee skullcap is predicted only to have nine (2040) or eight (2060) of the 19 currently extant populations remaining (50–60% of populations extirpated). Overall, representation is expected to decline in Scenario 1 with fewer Ocmulgee skullcap populations occurring in a narrower distribution across the species' range.

Scenario 2
Under Scenario 2 (status quo), future representation is predicted to decline slightly for the Ocmulgee skullcap (Table 5-6, Figure 5-3). At the 2040 and 2060 time steps, five populations are predicted to be extirpated in the Ocmulgee RU. In the Savannah RU, only one population is predicted to become extirpated by 2060 (no extirpations are predicted at 2040). However, 14 and 13 of 19 currently extant populations are predicted to remain extant at 2040 and 2060, respectively. Five and six populations are predicted to be extirpated in 2040 and 2060,

respectively. The extirpations are distributed throughout the portions of the Ocmulgee RU where the species occurs and the population predicted to be extirpated in the Savannah RU is not at the edge of the range. Therefore, although the number of populations is predicted to decline, the overall extent of the distribution of the populations in the two RUs is not reduced. Overall species representation is predicted to be reduced from current levels even under Scenario 2 with status quo management and conservation efforts.

Scenario 3
Under Scenario 3 (increased management and conservation), future representation is predicted to increase for Ocmulgee skullcap (Table 5-6; Figure 5-4). Only one population is predicted to be extirpated in 2040 and three populations are predicted to be extirpated in 2060. All predicted extirpations occur in the Ocmulgee RU and are due to stressors caused by development alone. The loss of these populations does not decrease the overall extent of the species range. The increased management and conservation efforts scenario includes augmentation, establishment, or reintroduction of additional populations within the species historical range. Overall, few extirpations are predicted under this scenario with no reduction of the species range and additional populations may be established. We have determined the overall species representation will increase from current levels under Scenario 3.

Summary of Future Species Representation
The loss of resilient populations within both representative units in indicates a potential decline in the species' adaptive capacity. A higher adaptive capacity may make a species better able to adjust in the face of changing environmental conditions. Under Scenario 1 (decreased management and conservation efforts), ten populations are predicted to be extirpated (seven in the Ocmulgee RU and three in the Savannah RU). Under Scenario 2 (status quo management), five populations are predicted to be extirpated by 2040 in the Ocmulgee RU and by 2060, six Ocmulgee skullcap populations are predicted to be extirpated (five in the Ocmulgee RU and one in the Savannah RU). Under Scenario 3 (increased management), one population in the Ocmulgee RU is predicted to be extirpated by 2040 and three populations are predicted to be extirpated by 2060. No populations are predicted to be extirpated in the Savannah RU under Scenario 3.

Under all three plausible future scenarios, the number of populations is decreased and distribution across the species range is reduced, although extant populations remain in both RUs under the conditions assessed. In addition, when populations are extirpated, connectivity between populations is reduced, further limiting potential genetic exchange between populations. Overall, representation declines under Scenario 1, declines slightly under Scenario 2 and increases slightly under Scenario 3.

5.4.3 Future Species Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. High redundancy "guards against irreplaceable loss of representation" (Redford *et al.* 2011 p. 42; Tear *et al.* 2005 p. 841) and minimizes the effect of localized extirpation on the range-wide persistence of a species (Shaffer and Stein 2000, p. 308). For a species to exhibit greater redundancy the populations should not be completely isolated and immigration and emigration between populations should be achievable. Redundancy for the Ocmulgee skullcap is characterized by having multiple resilient and representative populations distributed across the species' range.

Scenario 1

Under Scenario 1 (decreased management and conservation), resiliency is predicted to decline with extirpation of populations and subsequent reduced distribution of populations; therefore, future redundancy is predicted to decline for the Ocmulgee skullcap (Table 5-6, Figure 5-2). The Ocmulgee skullcap is currently represented by 1 highly resilient population, 2 moderately resilient populations, and 16 populations with low or very low resiliency in two representative units (watersheds) in two states. In Scenario 1, predicted changing conditions lead to the extirpation of 10 populations by 2040 and 11 by 2060.

Within the Ocmulgee RU, there are no highly or moderately resilient populations, six populations are predicted to have low or very low resiliency, and the remaining seven populations are predicted to be extirpated at 2040 and 2060. The extirpated populations are distributed throughout the RU with no particular area of concentration of population loss. In the Savannah RU, one population is predicted to have moderate resiliency, five populations) are predicted to have low or very low resiliency in 2040 and 2060. Three populations are predicted to be extirpated in 2040 with an additional population extirpated in 2060. The extirpations under this scenario in the Savannah RU occur in the most upstream and the most downstream portions of the current range. Loss of the three (2040) or four (2060) populations will lead to a contraction of the range in the Savannah RU with the two remaining population occupying the central portion of the RU (Figure 5-2).

In summary, all populations of Ocmulgee skullcap are predicted to have reduced resiliency at 2040 and 2060 under Scenario 1. At 2040 and 2060, Ocmulgee skullcap is predicted only to have nine (2040) or eight (2060) of the 19 currently extant populations remaining (50–60% of populations extirpated) with only one moderately resilient population remaining in the Savannah RU. Overall, redundancy is expected to decline in Scenario 1 with fewer, less resilient Ocmulgee skullcap populations with narrower distribution across the species' range.

Scenario 2

Under Scenario 2 (status quo), future redundancy is predicted to decline slightly for the Ocmulgee skullcap (Table 5-6, Figure 5-3). At the 2040 and 2060 time steps, five populations are predicted to be extirpated in the Ocmulgee RU; however, one population remains moderately resilient. The remaining seven populations in the Ocmulgee RU exhibit low or very low resiliency. In the Savannah RU, two highly or moderately resilient populations remain at 2040 and 2060, with only one population predicted to become extirpated by 2060. The remaining four (2040) or three (2060) populations are predicted to exhibit low or very low resiliency in the Savannah RU under Scenario 2. Under Scenario 2, the highly resilient population in the Savannah RU and the moderately resilient populations (one in each of the two RUs) are predicted to remain in the same condition in 2040 and 2060.

Overall, six populations experience declines in resiliency categories in 2040 and eight populations experience declines in 2060. No populations are expected to increase in resiliency under Scenario 2. However, 14 and 13 of 19 currently extant populations are predicted to remain extant at 2040 and 2060, respectively. Five and six populations are predicted to be extirpated in 2040 and 2060, respectively, with the majority of the populations expected to exhibit low or very low resiliency across both RUs. The populations predicted to be extirpated occur across the distribution in the Ocmulgee RU (five populations) and in the upstream portion of the Savannah RU (one population). Given reduced species resiliency in and extirpation of populations in both RUs, species redundancy is predicted to be reduced from current levels under Scenario 2 with status quo management and conservation efforts.

Scenario 3
Under Scenario 3 (increased management and conservation), future redundancy is predicted to increase for Ocmulgee skullcap (Table 5-6; Figure 5-4). Within the Ocmulgee RU, resilient populations are predicted to increase from one moderately resilient population to six moderately resilient and one highly resilient populations in 2040 and 2060. In the Ocmulgee RU, one and three populations are predicted to become extirpated due to development alone in 2040 and 2060, respectively. The loss of these populations does not decrease the overall extent of the species range. In the Savannah RU, resilient populations increase from two (BUN moderate and BUS high) in the current condition to three (BUN and BUS high and CAR moderate) in 2040. However, only the BUN and BUS populations remain highly resilient in 2060 and the CAR population decreases to low due to development.

Overall, under Scenario 3 in 2040, 15 populations (78%) exhibit an increase in resiliency category, 3 populations (16%) do not change, and one population (5%) declines in resiliency. Overall, under Scenario 3 in 2060, 11 populations (58%) exhibit an increase in resiliency category, 5 populations (26%) do not change, and 3 populations (16%) decline in resiliency. In addition, the increased management and conservation efforts scenario includes augmentation, establishment, or reintroduction of additional populations within the species historical range, providing increased redundancy for the species.

With increased conservation, Ocmulgee skullcap is predicted to have 18 to 16 extant populations in varying levels of resiliency occurring across both RUs. Given relatively few extirpations (only in the Ocmulgee RU) and the overall increase in resiliency for the majority of populations with both RUs maintaining resilient populations, overall redundancy is predicted to increase from current levels across the species' range. Overall, few extirpations are predicted under this scenario with no reduction of the species range and additional populations may be established.

Summary of Future Species Redundancy
The predicted declines in resiliency and extirpation of populations within both representative units in indicates a potential decline in the species' redundancy. Species redundancy is predicted to decline in Scenario 1, decline slightly in Scenario 2, and increase in Scenario 3 (Table 5-6 and Figures 5-2–5-4).

In Scenario 1 (decreased management), only one moderately resilient population remains (Savannah RU), and the other 11 extant populations predicted to be extant in 2040 and 2060 exhibit low or very low resiliency (Figure 5-2). Ten and 11 of the 19 currently extant populations are predicted to be extirpated in 2040 and 2060, respectively, in this future scenario (7 in the Ocmulgee RU and 3 in the Savannah RU). All populations are expected to experience a decline in resiliency category in 2040 and 2060.

In Scenario 2 (status quo management), redundancy declines slightly from the current condition. Five populations are predicted to be extirpated by 2040 in the Ocmulgee RU and by 2060, six Ocmulgee skullcap populations are predicted to be extirpated (five in the Ocmulgee RU and one in the Savannah RU). One moderately resilient population remains in the Ocmulgee RU and the

Savannah RU contains one population with moderate resiliency and one with high resiliency (Figure 5-3) at both time steps. In 2040, 31% of populations are predicted to experience a decline in resiliency category, rising to 42% of populations predicted to experience a decline in 2060.

In both Scenarios 1 and 2, populations on the upstream and downstream extent of the species' range either become extirpated or exhibit low or very low resiliency, which reduces the extent of the species range in future scenarios and decreases representation and redundancy.

In Scenario 3 (increase management), species redundancy improves with 10 (2040) or nine (2060) moderately or highly resilient populations rangewide. The increase in redundancy is primarily in the Ocmulgee RU, increasing from one to seven resilient populations. One population in the Ocmulgee RU is predicted to be extirpated by 2040 and three populations are predicted to be extirpated by 2060. No populations are predicted to be extirpated in the Savannah RU under Scenario 3. In this scenario, populations may be augmented or additional populations or occurrences established or reintroduced within the species historical range, leading to increased resiliency, number and distribution of populations.

Under future scenarios 1 and 2, the number and resiliency of populations is decreased and distribution of populations across the species range is reduced, although extant populations remain in both RUs under the conditions assessed. Fewer extirpations are predicted in Scenario 3 and most populations exhibit increased resiliency. Overall, redundancy declines under Scenario 1, declines slightly under Scenario 2 and increases slightly under Scenario 3.

5.5 Future Condition Summary

Projected urbanization and three plausible future scenarios (decreased, status quo, and increased levels of management) were evaluated to predict future Ocmulgee skullcap viability. Under Scenario 1 (decreased management), resiliency is decreased for all populations and 10 populations are predicted to be extirpated by 2040 and an additional population is predicted to be extirpated by 2060. All populations experience a decline in resiliency with one moderately resilient remaining. Under Scenario 2 (status quo management), resiliency is predicted to decrease for 31–42 percent of populations and five populations are predicted to be extirpated by 2040; six populations are predicted to be extirpated by 2060. Three populations with high or moderate resiliency remain under this scenario. Under Scenario 3 (increased management), resiliency changes are mixed, but overall there is an increase in population resiliency. However, one population is predicted to be extirpated by 2040 and three populations are predicted to be extirpated by 2060 in this scenario. Under all three plausible future scenarios, loss of at least one Ocmulgee skullcap population is predicted. Representation and resiliency are predicted to decline under scenarios 1 and 2, with an increase in redundancy predicted under an increased management scenario. The status quo scenario results in predicted declines in resiliency, representation, and redundancy and additional conservation measures may be needed to improve the long-term viability for the Ocmulgee skullcap.

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APPENDIX A. Current Condition Population Data

Table A-1. Ocmulgee skullcap population data used for current condition analysis.

				Population (pop) Attributes					Resiliency Scores for each Attribute							
EO Names	**Pop Name**	**Pop Code**	**Water-shed**	**#of EOs**	**No. of Individuals**	**No. of EOs/occurrences within pop**	**Change in # of EOs within a pop**	**Native Herb-aceous Ground Cover**	**No. of Individuals**	**No. of EOs within pop (plus patches)**	**Change in #. of EOs within a pop**	**Native Herb-aceous Ground Cover**	**Resiliency Score**	**Resiliency class**	**Pro-tected**	**Protec-tion notes**
James Dykes Memorial	James Dykes Memorial	JDM	Ocmulgee	1	54	4	stable	Moderate invasive exotic plant species; and/or deer browsing	1	3	2	1	7	mod	yes	Ocmulgee WMA (lease)
Robins AFB (E of Golf Course), Robins AFB (E of Ft Valley), Robins AFB (E of Golf Course2)	Robins AFB	RAB	Ocmulgee	3	3	4	stable	Moderate invasive exotic plant species; and/or deer browsing	0	3	2	1	6	low	yes	Robins AFB
Savage Branch (1, 2, 3)	Savage Branch	SVB	Ocmulgee	3	50	3	stable	Moderate invasive exotic plant species; and/or deer browsing	1	2	2	1	6	low	no	

				Population (pop) Attributes					Resiliency Scores for each Attribute							
EO Names	**Pop Name**	**Pop Code**	**Water-shed**	**#of EOs**	**No. of Individuals**	**No. of EOs/occurrences within pop**	**Change in # of EOs within a pop**	**Native Herb-aceous Ground Cover**	**No. of Individuals**	**No. of EOs within pop (plus patches)**	**Change in #. of EOs within a pop**	**Native Herb-aceous Ground Cover**	**Resiliency Score**	**Resiliency class**	**Pro-tected**	**Protec-tion notes**
I-75 Rest Area Bolingbroke	Bolingbroke Rest Area	BRA	Ocmulgee	1	8	2	stable	None or few invasive exotic plant species; presence of deer browsing	0	1	2	2	5	low	no	
Crooked Creek	Crooked Creek	CCR	Ocmulgee	1	31	2	stable	None or few invasive exotic plant species; presence of deer browsing	0	1	2	2	5	low	yes	Ocmulgee WMA (lease)
Jordan Creek	Jordan Creek	JDC	Ocmulgee	1	50	1	stable	Moderate invasive exotic plant species; and/or deer browsing	1	0	2	1	4	low	no	
Shellstone Creek	Shellstone Creek	SCT	Ocmulgee	1	46	1	stable	Moderate invasive exotic plant species; and/or	1	0	2	1	4	low	yes	Ocmulgee WMA (lease)

				Population (pop) Attributes					Resiliency Scores for each Attribute							
EO Names	Pop Name	Pop Code	Water-shed	#of EOs	No. of Individuals	No. of EOs/occurrences within pop	Change in # of EOs within a pop	Native Herb-aceous Ground Cover	No. of Individuals	No. of EOs within pop (plus patches)	Change in #. of EOs within a pop	Native Herb-aceous Ground Cover	Resiliency Score	Resiliency class	Pro-tected	Protec-tion notes
								deer browsing								
Dry Creek	Dry Creek	DYC	Ocmulgee	1	10	1	stable	Moderate invasive exotic plant species; and/or deer browsing	0	0	2	1	3	vlow	yes	Oaky Woods WMA lease
Oaky Woods WMA North	Oaky Woods WMA North	OWN	Ocmulgee	1	1	1	stable	Moderate invasive exotic plant species; and/or deer browsing	0	0	2	1	3	vlow	no	
Oaky Woods WMA South	Oaky Woods WMA South	OWS	Ocmulgee	1	1	1	stable	Moderate invasive exotic plant species; and/or deer browsing	0	0	2	1	3	vlow	yes	Oaky Woods WMA (lease)

				Population (pop) Attributes					Resiliency Scores for each Attribute							
EO Names	**Pop Name**	**Pop Code**	**Water-shed**	**#of EOs**	**No. of Individuals**	**No. of EOs/occurrences within pop**	**Change in # of EOs within a pop**	**Native Herb-aceous Ground Cover**	**No. of Individuals**	**No. of EOs within pop (plus patches)**	**Change in #. of EOs within a pop**	**Native Herb-aceous Ground Cover**	**Resiliency Score**	**Resiliency class**	**Pro-tected**	**Protec-tion notes**
River North Bluff	River North Bluff	RNB	Ocmulgee	1	1	1	stable	Moderate invasive exotic plant species; and/or deer browsing	0	0	2	1	3	vlow	no	
South Shellstone Creek	South Shellstone Creek	SSC	Ocmulgee	1	15	1	stable	Moderate invasive exotic plant species; and/or deer browsing	0	0	2	1	3	vlow	no	
Trib to Richland Creek	Trib to Richland Creek	TRC	Ocmulgee	1	6	1	stable	Moderate invasive exotic plant species; and/or deer browsing	0	0	2	1	3	vlow	no	
Yuchi WMA – South, Plant Vogtle, Hancock Landing,	Burke South	BUS	Savannah	4	319	6	Stable	None or few invasive exotic plant species; presenc	3	3	2	2	10	high	Yes	Mostly on Yuchi WMA, one EO on Plant Vogtle,

				Population (pop) Attributes					Resiliency Scores for each Attribute							
EO Names	Pop Name	Pop Code	Water-shed	#of EOs	No. of Individu als	No. of EOs/occu rrences within pop	Change in # of EOs within a pop	Native Herb-aceous Ground Cover	No. of Individua ls	No. of EOs within pop (plus patches)	Change in #. of EOs within a pop	Native Herb-aceous Ground Cover	Resiliency Score	Resiliency class	Pro-tected	Protec-tion notes
Yuchi WMA – Griffin Landing								e of deer browsin g								one private
Shell Bluff, McBean Creek, Boggy Gut Creek	Burke North	BUN	Savannah	3	112	3	decreasin g (one possibly 65extirpa ted)	None or few invasive exotic plant species; presenc e of deer browsin g	3	2	0	2	7	mod	no	
Georgia Visitor Center, Augusta Canal Gates, Fox Creek – Greystone Preserve, Fox Creek – Greg's Gas Station, Savannah River Bluffs HP	Columbia Richmon d	CAR	Savannah	5	450	6	decreasin g (one extirpate d)	High invasive exotic plant species; and/or deer browsin g	3	3	0	0	6	low	Yes	Central Savannah Land trust, SC State Park, 3 EOs not protected (one is on county land)

				Population (pop) Attributes					Resiliency Scores for each Attribute							
EO Names	**Pop Name**	**Pop Code**	**Water-shed**	**#of EOs**	**No. of Individuals**	**No. of EOs/occurrences within pop**	**Change in # of EOs within a pop**	**Native Herb-aceous Ground Cover**	**No. of Individuals**	**No. of EOs within pop (plus patches)**	**Change in #. of EOs within a pop**	**Native Herb-aceous Ground Cover**	**Resiliency Score**	**Resiliency class**	**Pro-tected**	**Protec-tion notes**
Barney Bluff	Barney Bluff	BAB	Savannah	1	50	1	stable	None or few invasive exotic plant species; presence of deer browsing	1	0	2	2	5	low	no	
Horse Creek	Horse Creek	HSC	Savannah	1	1	1	stable	Moderate invasive exotic plant species; and/or deer browsing	0	0	2	1	3	vlow	no	
Prescot Lakes – Wade Plantation	Prescott Lakes	PCL	Savannah	1	0	1	stable	Moderate invasive exotic plant species; and/or deer browsing	0	0	2	1	3	vlow	no	

APPENDIX B. Future Condition Population Development Risk Data

All Probabilities of Development (HIGH)							
POP	Current Habitat (Ha)	2040 HIGH habitat loss (Ha)	2040 HIGH habitat remaining	2040 HIGH %loss	2060 HIGH habitat loss (Ha)	2060 HIGH habitat remaining	% HIGH 2060 loss
BAB	206.83	110.71	96.12	53.53	133.18	73.66	64.39
BRA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BUN	534.80	0.00	534.80	0.00	0.00	534.80	0.00
BUS	202.30	20.72	181.58	10.24	41.23	161.07	20.38
CAR	612.22	222.53	389.69	36.35	255.96	356.26	41.81
CCR	300.03	3.37	296.65	1.12	3.37	296.65	1.12
DYC	587.54	249.45	338.09	42.46	292.21	295.33	49.73
HSC	85.62	31.38	54.24	36.65	44.26	41.36	51.69
JDC	0.91	0.00	0.91	0.00	0.08	0.83	8.34
JDM	188.15	0.00	188.15	0.00	0.49	187.66	0.26
OWN	848.93	41.78	807.16	4.92	58.73	790.21	6.92
OWS	207.38	103.09	104.29	49.71	132.34	75.04	63.82
PCL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RAB	205.18	3.52	201.66	1.71	3.52	201.66	1.71
RNB	0.51	0.30	0.21	58.71	0.30	0.21	58.71
SCT	380.27	3.40	376.87	0.89	16.04	364.24	4.22
SSC	41.58	0.00	41.58	0.00	0.00	41.58	0.00
SVB	5.05	4.56	0.48	90.44	4.53	0.52	89.68
TRC	462.44	0.00	462.44	0.00	0.03	462.42	0.01

APPENDIX C. Additional Future Condition Figures

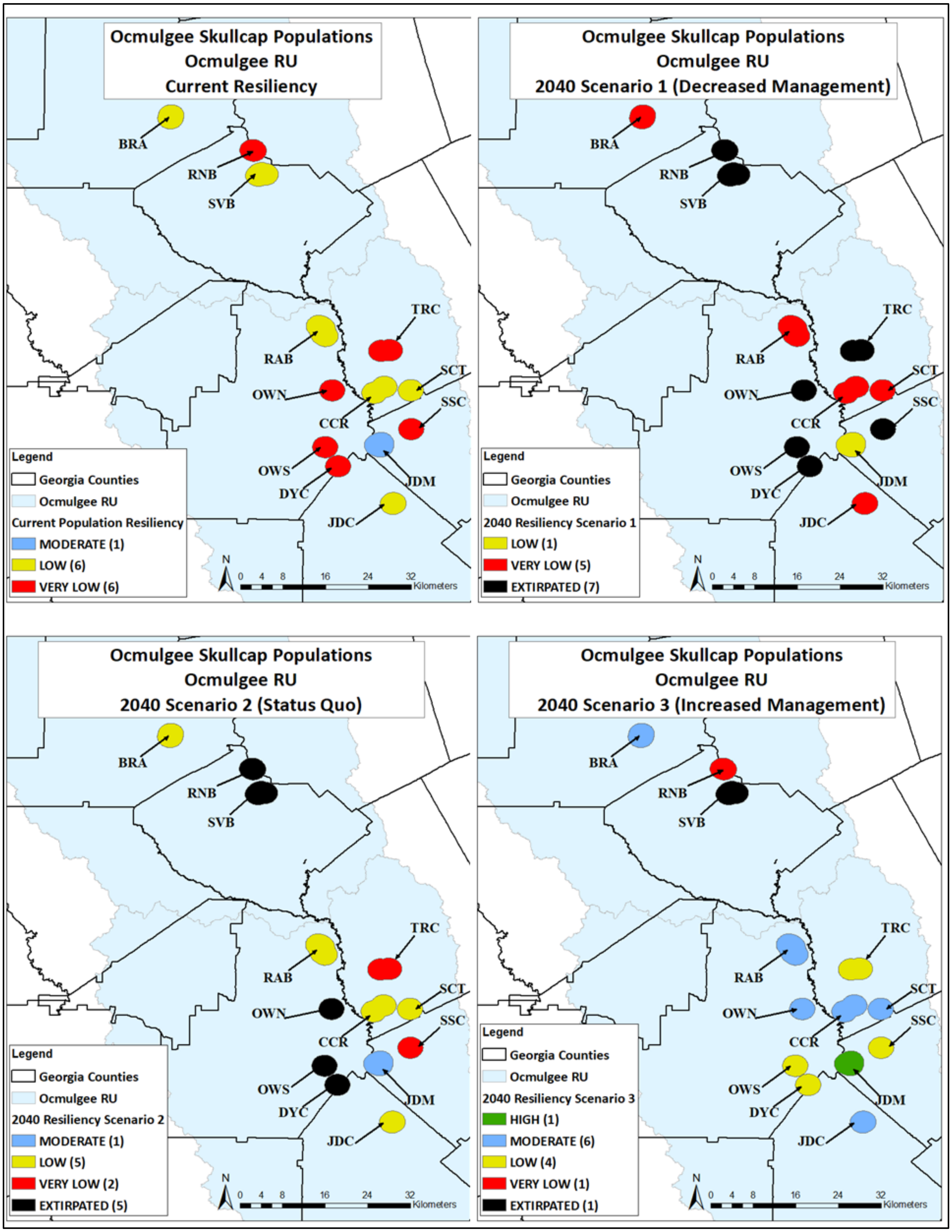

Figure C-1: Ocmulgee RU populations comparing current condition to year 2040 future scenarios 1 through 3.

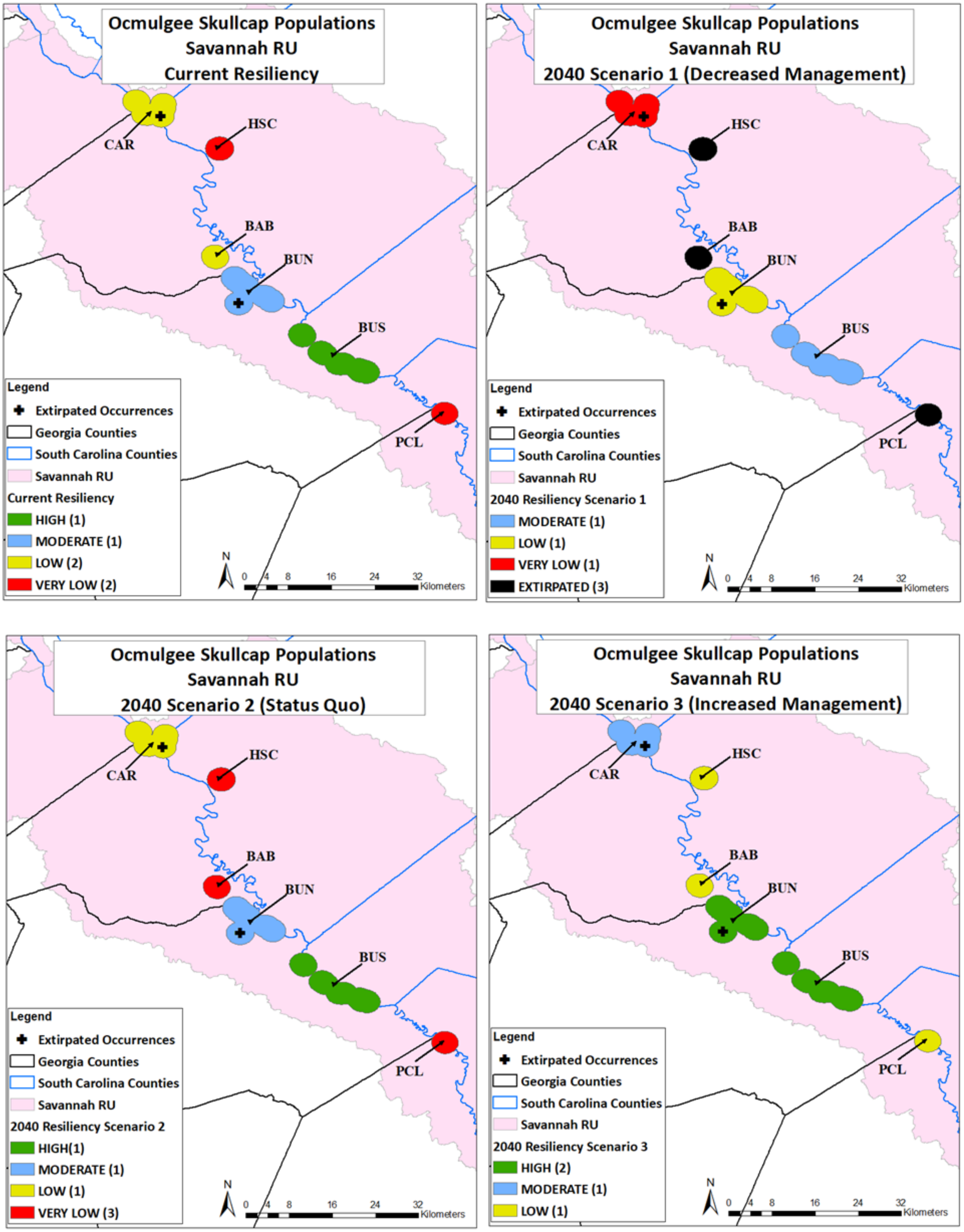

Figure C-2: Savannah RU populations comparing current condition to year 2040 future scenarios 1 through 3.

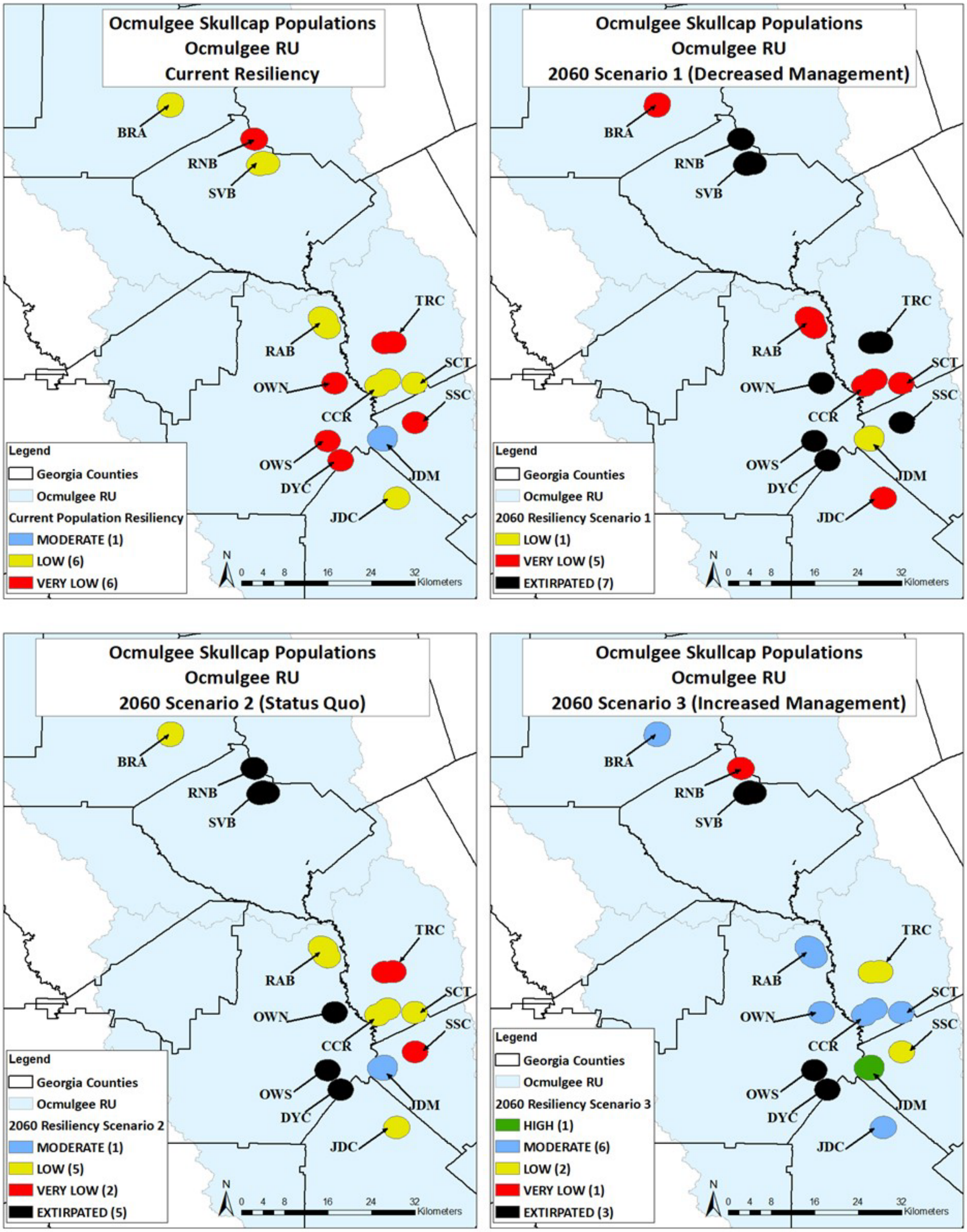

Figure C-3: Ocmulgee RU populations comparing current condition to year 2060 future scenarios 1 through 3.

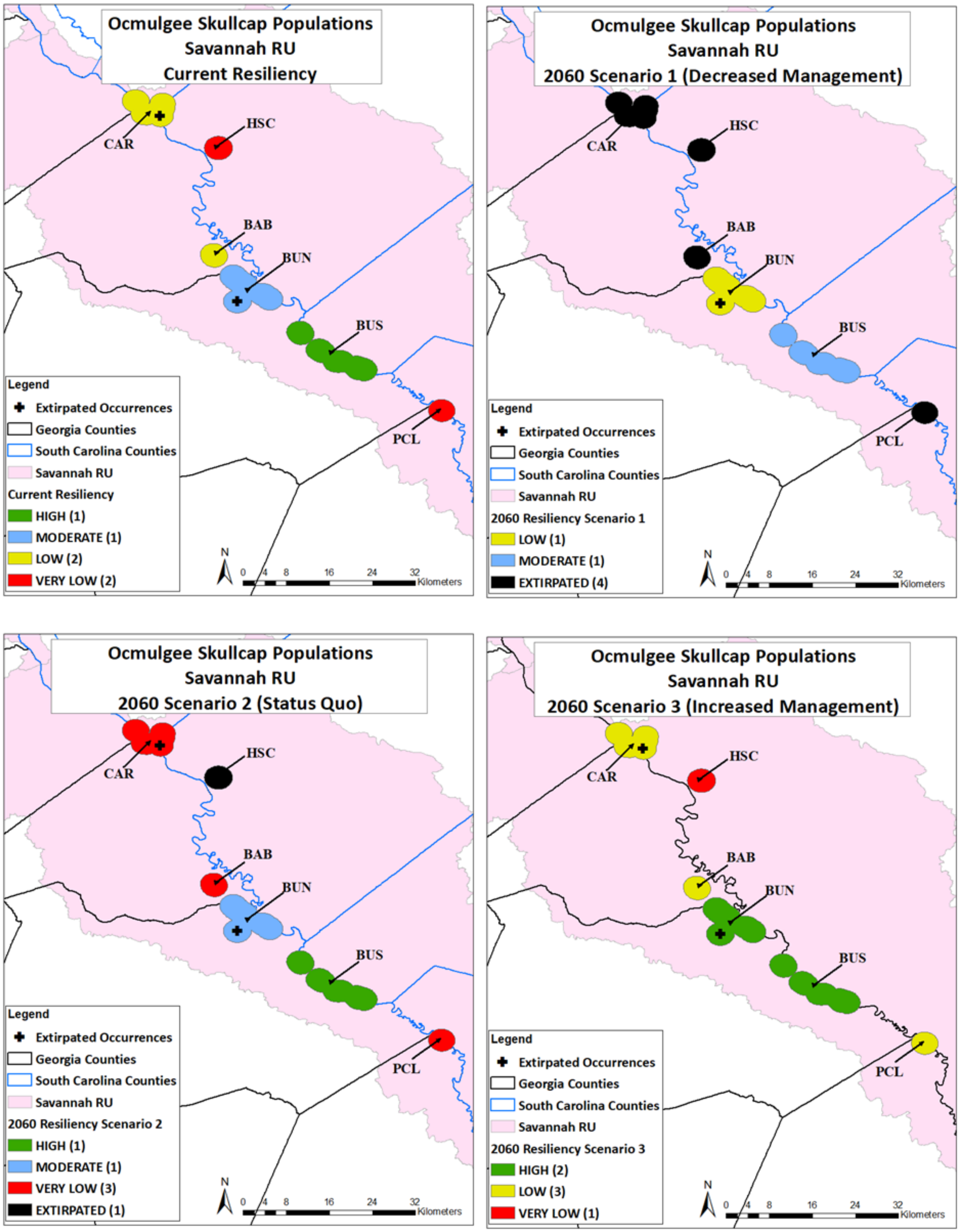

Figure C-4: Savannah RU populations comparing current condition to year 2060 future scenarios 1 through 3.