Recovery Outline
For
Arabis georgiana (Georgia rockcress)

September 2014

* Photo courtesy of Michelle Elmore, The Nature Conservancy.

This document outlines a preliminary course of action for the recovery of Georgia rockcress (*Arabis georgiana*) until a comprehensive recovery plan for the species is approved. The plant was listed as a threatened species under the Endangered Species Act of 1973 as amended (ESA) on September 12, 2014 (79 FR 54627). Georgia rockcress is a perennial herb that grows up to 90 centimeters (cm) (35 inches (in.)) tall. It grows in a variety of dry situations, including shallow soil accumulations on rocky bluffs, ecotones of sloping rock outcrops, and sandy loam along eroding riverbanks. It is occasionally found in adjacent mesic woods (or glades), but it will not persist in heavily shaded conditions. The primary threats to this plant include habitat destruction, modification, and fragmentation.

Listing and Contact Information:

Listing Classification:	Threatened range-wide
Effective Listing Date:	October 14, 2014
Lead Agency, Region:	U.S. Fish and Wildlife Service, Southeast Region
Lead Field Office:	Georgia Ecological Services Field Office, Athens, GA
Contact Biologist:	James Rickard, James_Rickard@fws.gov, 706-613-9493 x 223

Recovery Status Assessment

Species Description and Life History: *[Note: For a more detailed description of this species' biology and an assessment of listing factors, please refer to the proposed and final listing rules (78 FR 56192, September 12, 2013 and 79 FR 54627, September 12, 2014).]*

Georgia rockcress has basal leaves that are oblanceolate (lance-shaped but broadest above the middle and tapering toward the base), rounded at the apex, toothed on the margins, 4 to 8 cm (2 to 3 in.) long, and with or without long, tapered petioles. The basal leaves form a basal rosette and usually persist through the fruiting season with green lower surfaces. The stem leaves are alternate, lanceolate (lance-shaped) to narrowly elliptic, 1 to 5 cm (0.4 to 2.0 in.) long, and somewhat clasping around the stems. The upper surfaces of the stem leaves have stiff, branched hairs when young and are smoothish when mature. The flowers are borne in a terminal inflorescence (cluster at the tip of the stem) that is somewhat loosely branched. The fruit stands erect as a slender (1 mm or 0.04 in. wide), relatively long (5 to 7 cm or 2 to 3 in.) pod that splits in two, leaving behind a thin, papery, lengthwise partition. Flowering occurs from March to April, with fruiting beginning in May and into early July (Allison 1995; Patrick et al. 1995; Chafin 2007; Schotz 2010). There are two species known to be syntopic (occurring on same site) with Georgia rockcress that are easily misidentified as Georgia rockcress. They are *Boechera canadensis* and *B. laevigata*, previously assigned to the genus *Arabis* (Al-Shehbaz 2003). Georgia rockcress is primarily associated with high bluffs along major river courses, with dry-mesic to mesic soils of open rocky woodland and forested slopes, generally within regions underlain or otherwise influenced by granite, sandstone, or limestone.

Georgia rockcress grows in a variety of dry situations, including shallow soil accumulations on rocky bluffs, ecotones of sloping rock outcrops, and sandy loam along eroding riverbanks (Shotz 2010). It is occasionally found in adjacent mesic woods (or glades), but it will not persist in heavily shaded conditions. This species is adapted to high or moderately high light intensities, generally with a mature canopy providing partial shading; the habitat supports a relatively-closed to open canopy typified by *Juniperus virginiana* (eastern red cedar), *Ostrya virginiana* (American hophornbeam), *Quercus muehlenbergii (*chinquapin oak), *Fraxinus americana* (white ash), *Acer barbatum* (southern sugar maple), and *Cercis canadensis* (eastern redbud). The combination of a mature canopy on extreme slope with shallow soils lends this habitat to discrete disturbance events with wind-thrown trees or sloughing soils that create canopy gaps and preclude leaf litter accumulation. Georgia rockcress exploits the exposed soil and increased light created by canopy gap dynamics. A rich diversity of grasses and forbs characterize the herb layer, including *Carex cherokeensis* (Cherokee sedge), *Bromus purgans* (hairy woodland brome), and many more. In addition, 2 species easily misidentified as Georgia rockcress occur in these habitats: *Boechera canadensis* and *B. laevigata*, previously assigned to the genus *Arabis* (Al-Shehbaz 2003). Confusion with the two *Boechera* taxa could lead to an overestimate of abundance for Georgia rockcress.

Distribution and Abundance: This species occurs on soils that are circumneutral (having neutral pH) to slightly basic (or buffered) in the Lower Gulf Coastal Plain, Upper Gulf Coastal Plain, Red Hills, Black Belt, Piedmont, and the Ridge and Valley Physiographic Provinces (Schotz 2010). Allison (1995) conducted the first comprehensive survey for this species and compiled existing data on known occurrences. As part of this effort, he surveyed 205 sites over nine counties in Georgia and discovered only four previously unknown populations (a 2 percent success rate). Schotz (2010) visited a total of 44 sites; 14 of the 16 historically occupied sites were still extant, but only 1 of 28 previously-unsurveyed sites

supported Georgia rockcress. Currently, 18 populations are documented to occur across Alabama and Georgia. Twelve of these occur solely in Alabama; five solely in Georgia; and one extends into both States (for a summary of surveys on this plant, see end of this document).

Life History/Ecology: Georgia rockcress generally occurs on steep river bluffs often with shallow soils overlaying rock or with exposed rock outcroppings. These edaphic conditions result in micro-disturbances, such as sloughing soils with limited accumulation of leaf litter or canopy gap dynamics, possibly with wind-thrown trees, which provide small patches of exposed mineral soil in a patchy distribution across the river bluff (Schotz 2010). While Georgia rockcress needs small-scale disturbances with slightly increased light, limited competition for water, and exposed soils for seed germination, the species is a poor competitor and is easily outcompeted by aggressive competitors (Alison 1995; Moffett 2007; Schotz 2010). Natural large-scale disturbances, such as fire and catastrophic flooding, are unlikely to occur on the steep river bluffs occupied by Georgia rockcress. However, human-induced disturbance has fragmented river bluff habitats and created conditions favorable to invasion of nonnative species.

Populations of Georgia rockcress are healthiest in areas receiving full or partial sunlight. This species seems to be able to tolerate moderate shading, but it exists primarily as vegetative rosettes in heavily shaded areas (Moffett 2007). Those populations occurring in forested areas will decline as the forest canopy closes. Allison (1999) attributed the decline of a population in Bibb County, Alabama, to canopy closure. In addition, the small number of individuals at the majority of the sites makes these populations vulnerable to local extinctions from unfavorable habitat conditions such as extreme shading.

Genetics: This species is composed of three genetic groups: a North Georgia group, a Middle Georgia group, and an Alabama group (Garcia 2012). While the Middle Georgia genetic group contains the largest populations (Goat Rock Dam and Fort Benning) and is the most important to the conservation of this species, the smaller populations in the North Georgia and Alabama genetic groups are more vulnerable to localized extirpation and represent an important conservation element for this species. Any threats that remove or further deteriorate populations can also have a detrimental effect on the existing genetic diversity of the species.

Critical Habitat: [*Note: For a more detailed description of the critical habitat designated for this species, please refer to the proposed and final critical habitat* rules (78 FR 56506, September 12, 2013 and 79 FR 54635 published on September 12, 2014.]

We designated 17 critical habitat units, containing 732 acres of critical habitat for Georgia rockcress (Table 1, end of the document). All critical habitat units provide primary constituent elements specific to Georgia rockcress, including:

- Large river bluffs with steep and/or shallow soils that are subject to localized disturbances that limit the accumulation of leaf litter and competition within the Lower Gulf Coastal Plain, Upper Gulf Coastal Plain, Red Hills, Black Belt, Piedmont, and Ridge and Valley Physiographic Provinces of Georgia and Alabama.

- Well-drained soils that are buffered or circumneutral generally within regions underlain or otherwise influenced by granite, sandstone, or limestone.
- A mature, mixed-level canopy with spatial heterogeneity, providing mottled shade and often including species such as eastern red cedar, America hophornbeam, chinquapin oak, white ash, southern sugar maple, and redbud with a rich diversity of grasses and forbs characterizing the herb layer.
- Intact habitat that is fully functional (i.e., with mature canopy and discrete disturbances) and buffered by surrounding habitat to impede the invasion of competitors.

Threat Assessment

Historically, suitable habitat for this species was destroyed by quarrying, residential development, timber harvesting, road building, recreation, and hydropower dam construction; one or more of these activities pose ongoing current threats to all known populations (Table 2, end of the document). Given the extremely small size of Georgia rockress populations, projects that destroy even a small amount of habitat can have a serious impact on this species, including existing genetic diversity of the species.

Currently, the primary threat to extant populations of Georgia rockcress is the ongoing invasion of nonnative species into suitable habitat. Quarrying, residential development, timber harvesting, road building, recreation sites (such as campsites or mowing of fields) and other activities open the canopy, destroy soil profiles and disrupt hydrology. These changes fragment Georgia rockcress, creating more edge habitat and promoting invasion of nonnative species (Honu and Gibson 2006). Edges function as sources of propagules for disturbed habitats and represent complex environmental gradients with changes in light availability, temperature, humidity, wind speed, and soil moisture, with plant species responding directly to environmental changes (Meiners et al. 1999). Edge effect, including any canopy break due to timber harvest, fields, or maintained rights-of-way, may penetrate as far as 175 meters (574 feet), resulting in changes in community composition (Fraver 1994; Meiners et al. 1999; Gehlhausen et al. 2000; Honu and Gibson 2006).

Human disturbance of 17 of the 18 known Georgia rockcress sites has provided opportunities for the invasion of aggressive, nonnative weeds, especially *Lonicera japonica* (Japanese honeysuckle). This species is a gap adaptor that can easily invade disturbed areas to 90 meters (295 feet) into a forested habitat (Honu and Gibson 2006). Other nonnatives include *Melia azedarach* (Chinaberry or bead-tree), *Pueraria montana* var. *lobata* (kudzu), *Albizia julibrissin* (mimosa), *Ligustrum japonica* (Japanese privet), *Ligustrum sinense* (Chinese privet), *Lygodium japonicum* (Japanese climbing fern), and *Microstegium vimineum* (Nepalese browntop) (Alison 1995; Moffett 2007; Schotz 2010). While edge habitats are subject to invasion of nonnative species, a more limited group of nonnative plants can then invade closed-canopy habitats; species with a rosette form, like Georgia rockcress, are more susceptible to exclusion by some nonnatives (Meiners et al. 1999). Georgia rockcress is not a strong competitor and is usually found in areas where growth of other plants is restrained due to the shallowness of the soils or the dynamic status of the site (e.g., eroding riverbanks) (Allison 1995; Moffett 2007). However, nonnative species are effectively invading these riverbank sites, and the long-term survival of at least five populations in the Coastal Plain

province is questionable (Allison 1995). This species is only able to avoid competition with nonnative species where the soil depth is limited (e.g., rocky bluffs) (Allison 1995; Moffett 2007)

Competition from nonnative species, exacerbated by adjacent land use changes, likely contributed to the loss of the population at the type locality in Stewart County, Georgia (Allison 1995), and possibly to one of the Bibb County, Alabama, populations and several other sites in this general area (Allison 2002, pers. comm.; Alabama Natural Heritage Program 2004). Additional populations are also currently being negatively affected by competition with nonnative plants. According to Moffett (2007), most of the sites in Georgia are being impacted by the presence of invasive plant species, primarily Japanese honeysuckle, Chinese privet, and Nepalese browntop. Japanese honeysuckle was observed growing on individual plants of Georgia rockcress at three sites visited by Allison in 1995. At a fourth site, plants growing in a mat of Nepalese browntop declined in number from 27 individuals in 1995 (Allison 1995) to 3 in 2006 (Moffet 2007). Allison (1995; Allison 1999) considered four other populations to be imminently threatened by the nearby presence of nonnative plants. Thus, approximately 40 percent of the populations visited by Allison in 1995 were reportedly threatened by nonnative species. By 2007, Moffett (2007) reported all six of the Georgia rockcress populations in Georgia were threatened by nonnative species. By 2010, Schotz (2010) reported 9 of the 13 populations in Alabama were impacted by nonnative species. Currently, 14 of the 18 extant populations are threatened by nonnatives. Other natural or manmade factors affecting the continued existence of Georgia rockcress include nonnative plant encroachment and genetic consequences of small populations. Climate change may also be a factor, although currently we do not have enough information on the local effects of climate change to conclusively determine that climate change is a specific threat to Georgia rockcress.

Climate change will be a particular challenge for biodiversity because the interaction of additional stressors associated with climate change and current stressors may push species beyond their ability to survive (Lovejoy 2005). Current climate change predictions for terrestrial areas in the Northern Hemisphere indicate warmer air temperatures, more intense precipitation events, and increased summer continental drying (Field et al. 1999; Hayhoe et al. 2004; Cayan et al. 2005; Intergovernmental Panel on Climate Change (IPCC) 2007). Climate change may lead to increased frequency and duration of severe storms and droughts (McLaughlin et al. 2002; Cook et al. 2004; Golladay et al. 2004).

Severe drought would be expected to have an effect on the plant community, including the mature canopy and canopy gap dynamic, and increased storm intensity could accelerate erosion-related disturbances; however, the information currently available on the effects of global climate change and increasing temperatures does not make sufficiently precise estimates of the location and magnitude of the effects. In addition, we are not currently aware of any climate change information specific to the habitat of the Georgia rockcress that would indicate which areas may become important to the species in the future.

Given the small number of total plants in many populations, and that the species is distributed as disjunct populations across five physiographic provinces in three major river systems, each population is important to the conservation of genetics for the species (Garcia

2012). Only the Goat Rock Dam and Fort Benning populations are sufficiently large (greater than 1,000 individuals) to preclude a genetic bottleneck (Moffett 2007; Schotz 2010). A genetic bottleneck would result in reduced genetic diversity with mating between closely related individuals, which can lead to reduced fitness due to inbreeding depression (Ellstrand and Elam 1993).

In summary, population declines in Georgia rockcress populations have been attributed to competition from nonnatives and also heavy shading associated with canopy closure. Nonnative species are an immediate threat that is severely impacting Georgia rockcress throughout its range. Those populations with only a few individual plants are threatened with local extinction, which can also contribute to the loss of genetic diversity for the species as a whole. Therefore, we have determined that other natural or manmade factors currently pose an imminent and high degree of threat to Georgia rockcress.

Conservation Assessment:

Legal Protection: Georgia rockcress is listed as threatened by the State of Georgia (Patrick et al. 1995; Chaffin 2007). This State listing provides legal standing under the Georgia Wildflower Preservation Act of 1973 (O.C.G.A. 12-6-170), which prohibits the removal of this and other wildflower species from public land and regulates the taking and sale of plants from private land. This law also triggers the Georgia Environmental Protection Act process in the event of potential impacts to a population by State activities on State-owned land (Moffett 2007). However, the greater problem of habitat destruction and degradation is not addressed by this law (Patrick et al. 1995); therefore, there is no protection from projects like road construction, construction of reservoirs, installation of utility lines, quarrying, or timber harvest that degrade or fragment habitat. In Alabama, there is no protection or regulation, either direct or indirect, for Georgia rockcress (Schotz 2010).

Land Protection and Population Conservation: Conservation efforts by The Nature Conservancy (TNC) in Bibb County, Alabama, have included acquisition of the entire population of Georgia rockcress at Browns Dam Glade and a small portion of the Cottingham Creek Bluff population, and the Six Mile Creek population.

The Blacks Bluff Preserve population, Floyd County, Georgia, is in private ownership protected with a conservation easement held by TNC. There were 27 Georgia rockcress reported here in 1995; although, nonnative species have since extirpated Georgia rockcress from this site. The Georgia Plant Conservation Alliance (GPCA) and TNC agreed to bolster the existing population with plants grown from seed collected at the two nearby (Ridge and Valley physiographic province) populations: Whitmore Bluff and Resaca Bluffs. The Chattahoochee Nature Center collected seed and grew 35 plants from Whitmore's Bluff and 65 plants from Resaca Bluffs. In 2008, 100 Georgia rockcress were planted in this unit; 31 Georgia rockcress were counted on this site during 2013 surveys (Goldstrohm 2013). In April 2013, an additional 15,000 seeds were sown directly onsite to recruit new plants to this population (Goldstrohm 2013).

Two populations are federally owned, and two are owned by the State of Alabama. In Federal ownership, the entire Fern Glade population, Bibb County, Alabama, occurs on the USFWS' Cahaba National Wildlife Refuge. Also, the entire population at Fort Benning,

located along the banks of the Chattahoochee River in Russell County, Alabama, and Chattahoochee County, Georgia, is in Federal ownership. The Department of Defense is working with TNC to monitor and provide for conservation of the Fort Benning populations (Elmore 2010). Fort Benning has updated their integrated natural resources management plan (INRMP) to address Georgia rockcress (INRMP 2014). The Fort Benning INRMP excludes timber management in occupied habitat and establishes a monitoring effort coupled with management of invasive speices. The State of Alabama owns Fort Tombecbee in Sumtner County and Fort Toulouse State Park in Elmore County, there is no particular protection afforded to the Georgia rockcress on these State-owned properties.

The majority of the Goat Rock Dam population in Georgia (Harris/Muscogee Counties) is located on buffer lands of the Georgia Power Company and receives some protection from a shoreline management plan with vegetative management buffers to prohibit disturbance and protect Georgia rockcress; this management plan was developed during Federal Energy Regulatory Commission (FERC) licensing (FERC 2004; Moffett 2007). The southernmost portion of the Goat Rock Dam population is privately owned.

In total, at least some portion of nine populations are owned by potential conservation partners; however, only the Fort Benning population has a formal management plan to benefit Georgia rockcress. Only the Goat Rock Dam and Blacks Bluff populations have had any effort directed to managing for Georgia rockcress. These populations are afforded varying degrees of protection, and while none of these are likely to be developed, they could be subject to other impacts including recreation, road construction, inappropriate timber harvest, and continued pressure from invasive species.

PRELIMINARY RECOVERY STRATEGY

A. RECOVERY PRIORITY NUMBER WITH RATIONALE

Georgia rockcress is assigned a recovery priority of 8, which indicates that species faces a moderate degree of threat and demonstrates a high recovery potential. The threat level for this species is considered moderate, because the threats are ongoing and occur across the species' range but are unlikely to impact all populations equally. The recovery potential for Georgia rockcress is high because the biological and ecologically limiting factors for this species are relatively well understood. Active management will be needed to maintain populations. The threats to the species' existence are primarily habitat related and could be alleviated through habitat restoration, protection, and management.

B. RECOVERY STRATEGY

The recovery strategy for Georgia rockcress will involve a significant amount of outreach and work with private and public landowners. There are 18 known extant occurrences of Georgia rockcress, and 17 occurrences were designated as critical habitat. While these critical habitat sites will initially be the focus for protection and management, the Service and its partners will take advantage of opportunities to benefit the species, where those opportunities present themselves. Work with these landowners and others will be critical for the recovery of Georgia rockcress.

Management of disturbance, invasive species, and forest fragmentation are likely to be the most widely required management activities for this species. Additionally, an

increased understanding of how the populations do or do not interact with each other will be necessary for determining what impact habitat fragmentation has had on the genetic diversity of this species and the importance of proximity of protected occurrences for the recovery of the species.

This genetic information will be important as the role of seed collection and population augmentation and re-introductions become more fully developed. The Service expects that information regarding the genetic diversity at and between sites will be used to drive the identification of appropriate recipient sites for donor seed. While the species is still broadly distributed within its narrow range and there are a relatively high number of occurrences remaining, most of these sites are in private ownership and under threat from future development. As such, opportunities to provide protected and managed habitats for this species should be capitalized upon, with considerations of population augmentation or reintroduction where appropriate, particularly to bolster the smaller populations with fewer than 50 individuals.

The Service's initial recovery implementation will involve working with our partners and the public to protect, conserve, and restore appropriate glade or rockoutcrop habitats.

C. INITIAL ACTION PLAN

Recovery needs for Georgia rockcress include continued surveys and monitoring, threat abatement, and research:

1. Continue public outreach to provide education and explore opportunities to work on private property.
2. Develop and implement management strategies for the species to include aspects like invasive species control.
3. Conduct regular monitoring at all accessible sites.
4. Conserve and manage existing populations and habitat.
5. Establish methods to effectively reintroduce and monitor Georgia rockcress.
6. Enhance the suitability of known sites and potential reintroduction sites.
7. Conserve germplasm (genetic material; e.g. seed) and promote genetic diversity.
8. Conduct studies of genetic variation within and between known sites.
9. Determine the minimum number of populations required to ensure survival of Georgia rockcress.
10. Define population regulation factors.
11. Look for opportunities to protect existing occurrences through acquisition, easements and/or management agreements.
12. Develop and implement management strategies for the GA rockcress, initially with the two State parks in Alabama.

PREPLANNING PROCESS

We will prepare a recovery plan for Georgia rockcress that includes objective and measurable criteria which, when met, will ensure conservation of the species. Recovery criteria will address all meaningful threats to the species, as well as estimate the time and the cost to achieve recovery. The recovery plan will be developed by the Georgia Ecological Services Field Office. At the present time, this species does not warrant the appointment of a formal recovery team.

The Service will coordinate recovery implementation efforts with an informal network of experts and involved parties. A recovery team may be formally appointed later, if deemed necessary. Periodically, meetings among these parties may be convened for the purpose of sharing information and ideas about advancing Georgia rockcress recovery. The draft recovery plan should be finalized and sent to the Regional Office for review in September 2015. The final recovery plan should be finalized and sent to the Regional Office for review by September 2016, although this timeline may be affected by available resources and regional priorities.

During the recovery planning process, input, comments and review will be sought from multiple stakeholders within Alabama and Georgia. These will include State and Federal agencies, industrial and agricultural groups, research universities, and conservation organizations.

Approved:

Assistant Regional Director, Region 4
U.S. Fish and Wildlife Service

2/12/15
Date

References

Alabama Department of Conservation and Natural Resources. 2005. Conserving Alabama's Wildlife: A Comprehensive Strategy. Alabama Department of Conservation and Natural Resources, Wildlife and Freshwater Fisheries Division, Montgomery, Alabama. 322 pp.

Alabama Natural Heritage Program. 2004. Report for Georgia rockcress, *Arabis georgiana*, Monitoring and Restoration Agreement No. 1448-40182-02-112. 4 pp.

Al-Shehbaz, I.A. 2003. Transfer of most North American species of *Arabis* to *Boechera* (Brassicaceae). Abstract. Novon 13:381-391.

Allison, J.R. 1995. Status survey of *Arabis georgiana* Harper (Georgia rockcress) in Georgia. Unpublished report for the U.S. Fish and Wildlife Service. Jackson, MS. 18 pp. + appendices.

Allison, J.R. 1999. Populations of *Arabis georgiana* discovered in 1998. Unpublished report for the U.S. Fish and Wildlife Service. Jackson, MS. 7 pp.

Allison, J. R. 2002. Telephone interview, Georgia Department of Natural Resources, Social Circle, Georgia. February 25, 2002.

Cayan, D., Dettinger, M., Stewart, I., and Knowles, N. 2005. Recent changes towards earlier springs: early signs of climate warming in western North America: Watershed Management Council

Networker, Spring 2005, p. 3-7. U.S. Geological Survey, Scripps Institution of Oceanography, La Jolla, California.

Chafin, L. G., 2007. Field Guide to the Rare Plants of Georgia. The State Botanical Garden of Georgia, Athens, Georgia. 526 pp.

Cook, E.R., Woodhouse, C.A., Eakin, C.M., Meko, D.M., and Stahle, D.W. 2004. Long-Term Aridity Changes in the Western United States. Science, November 5, 2004: Vol. 306 no. 5698. pp. 1015-1018. Published online October 7, 2004. DOI: 10.1126/science.1102586

Elmore, M. 2009. Email to Cary Norquist, The Nature Conservancy, Fort Benning, Georgia. February 20, 2009.

Elmore, M. 2010. Telephone interview, The Nature Conservancy, Fort Benning, Georgia. March 4, 2010.

Elmore, M. 2010. *Arabis georgiana* update on Georgia populations. Unpublished report. Jackson, Mississippi. 4 pp.

Ellstrand, N. C., and Elam, D. R. 1993. Population Genetic Consequences of Small Population Size: Implications for Plant Conservation. Annual Review of Ecology and Systematics, Vol. 24 (1993), pp. 217-242.

Forman R.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R.L., Goldman, C.R., Heanue, K., Jones, J., Swanson, F., Turrentine, T., and Winter, T.C.. 2002. Road Ecology: Science and Solutions. Island Press, Washington, D.C. 504 pp.

Fraver, S. 1994. Vegetation responses along edge-to-interior gradients in the mixed hardwood forests of the Roanoke River Basin, North Carolina. *Conservation Biology* 8(3): 822-832.

FERC 2004. Middle Chattahoochee FERC license. United States of America 109 FERC 62, 246 Federal Energy Regulatory Commission. 36 pp.

Field, C.B., Daily, G.C., Davis, F.W., Gaines, S., Matson, P.A., Melack, J., and Miller, N.L. 1999. Confronting climate change in California. Ecological impacts on the Golden State. A report of the Union of Concerned Scientists, Cambridge , Massachusetts, and the Ecological Society of America, Washington, DC.

Garcia, A. M. 2012. Demographic and genetic consequences of small population size in remnant populations of *Arabis georgiana* Harper (Georgia rockcress). Thesis. Columbus State University. 59 pp.

Georgia Department of Natural Resources, Wildlife Resources Division. 2005. A Comprehensive Wildlife Conservation Strategy for Georgia, 202 pp. 14 Appendices.

Gehlhausen, S. M., Schwart, M.W., and Augspurger, C.K. 2000. Vegetation and microclimatic edge effects in two mixed-mesophytic forest fragments. Plant Ecology 147: 21-35.

Goldstrum, B., von Schmeling, H., Hodges, M., and Brown, C. 2010. Blacks Bluff *Arabis* outplanting. Unpublished report. 2 p.

Goldstrum, B. and Brown, C. 2013. Blacks Bluff *Arabis* outplanting. Unpublished report. 2 p.

Golladay, S.W., Gagnon, P.G., Kearns, M., and others. 2004. Response of freshwater mussel assemblages (Bivalvia:Unionidae) to a record drought in the Gulf Coast Plain of southwestern Georgia. J N Am Benthol Soc 23(3):494-506.

Hannah, L. and Lovejoy, T.E. 2003. Climate change and biodiversity: Synergistic Impacts. Advances in Applied Biodiversity Science 4:1–123.

Harper, R.M. 1903. A new *Arabis* from Georgia. Torreya 3:87-88.

Harper, R.M. 1904. A new station for *Arabis georgiana*. Torreya 44:24-25.

Harper, R.M. 1906. Notes on the distribution of some Alabama plants. Bull. Torr. Bot. Club 33:532.

Hayhoe, K., Cayan, D., Field, C.B., Frumhoff, P.C., Maurer, E.P., Miller, N.L., Moser, S.C., Schneider, S.H., Cahill, K.N., Cleland, E.E., Dale, L., Drapek, R., Hanemann, R.M., Kalkstein, L.S., Lenihan, J., Lunch, C.K., Neilson, R.P., Sheridan, S.C., and Verville, J.H. 2004. Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences of the United States of America (PNAS). 101(34):12422-12427.

Hodges, M. 2005. Email to Cary Norquist, The Nature Conservancy. Atlanta, Georgia. March 24, 2005.

Honu, Y. A. K. and D. J. Gibson. 2006. Microhabitat factors and the distribution of exotic species across forest edges in temperate deciduous forest of southern Illinois, USA. Journal of the Torreya Botanical Society 133(2), 2006. pp. 255-266.

Hopkins, M. 1937. *Arabis* in eastern and central North America. Rhodora 39:63-98, 106-148, 155-186, plates 457-458.

Intergrated Natural Resource Management Plan. 2014. Fort Benning Georgia

IPCC (Intergovernmental Panel on Climate Change). (2007) Climate change 2007: the physical science basis. In: Solomon, S; Qin, D; Manning, M; et al.; eds. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Lovejoy, T.E. 2005. Conservation with a changing climate. Pages 325–328 in Lovejoy, T.E. and Hannah, L., editors. Climate change and biodiversity. Yale University Press, New Haven, Connecticut.

McLaughlin, J.F., Hellmann, J.J., Boggs, C.L., and Ehrlich, P.R. 2002. Climate change hastens population extinctions. PNAS 99:6070-6074.

Meiners, S. J. and Pickett, S. T. A. 1999. Changes in community and population responses across a forest-field gradient. – Ecography 22: 261-267.

Moffett, J.M. Jr. 2005. Email to Cary Norquist, Georgia Department of Natural Resources. Social Circle, Georgia. March 15, 2005.

Moffett, J.M., Jr. 2007. Report on Conservation Actions for Georgia Rockcress (*Arabis georgiana*) in Georgia. Order No. 14448043910-2-M713A. 7 pp. + appendices.

Patrick, T.S., J.R. Allison, and G.A. Krakow. 1995. Protected Plants of Georgia. Georgia Department of Natural Resources, Wildlife Resources Division, Social Circle. 246 pp.

Schotz, A. 2007. Email to Cary Norquist, Alabama Natural Heritage Program. Montgomery, Alabama. March 7, 2007.

Schotz, A. 2009. Email to Cary Norquist, Alabama Natural Heritage Program. Montgomery, Alabama. February 12, 2009.

Schotz, A. 2010. Status Assesment of Arabis georgiana Harper (Brassicaceae), the Georgia rockcress, in Alabama. Alabama Natural Heritage Program, Auburn University, Alabama. Unpublished Report for the U.S. Fish and Wildlife Service. 63pp.

Table 1. Final critical habitat units for Georgia rockcress. Area estimates reflect all land within critical habitat unit boundaries.

Unit #	Unit Name	County/State	Ownership	Hectares	Acres
1	Fort Tombecbee	Sumter/AL	State	6	14
2	Marshalls Bluff	Monroe/AL	Private	11	27
3	Prairie Bluff	Wilcox/AL	Private	13	32
4	Portland Landing River Slopes	Dallas/AL	Private	12	31
5	Durant Bend	Dallas/AL	Private	12	28
6	Murphys Bluff Bridge Cahaba River	Bibb/AL	Private	11	26
7A	Creekside Glades	Bibb/AL	Private	11	26
7B	Little Schulz Creek	Bibb/AL	Private	12	28
8A	Cottingham Creek Bluff	Bibb/AL	Private	22	55
8B	Pratts Ferry	Bibb/AL	Private	11	28
9A	Fern Glade	Bibb/AL	Federal	14	34
9B	Sixmile Creek	Bibb/AL	Private	13	31
10A	Browns Dam Glade North	Bibb/AL	Private	14	35
10B	Browns Dam Glade South	Bibb/AL	Private	15	37
11	McGuire Ford | Limestone Park	Bibb/AL	Private	6	15
12	Fort Toulouse State Park	Elmore/AL	State	7	17
13	Fort Gaines Bluff	Clay/GA	Private	17	42
14A	Goat Rock North	Harris/GA	Private	7	19
14B	Goat Rock South	Harris, Muscogee/GA	Private	24	59
15	Blacks Bluff Preserve	Floyd/GA	Private	37	92
16	Whitmore Bluff	Floyd/GA	Private	17	43
17	Resaca Bluffs	Gordon/GA	Private	5	13
			TOTAL	297	732

Note: Area sizes may not sum due to rounding.

Table 2. Impacts to populations of Georgia rockcress from human-induced factors and nonnative plants.

Site Name	County/State	Human-Induced Impact (Factor A)	Impacted by Nonnative Plants (Factor E)
Fort Tombecbee	Sumter/AL	Road with bridge, Housing, Commercial	None
Marshalls Bluff	Monroe/AL	Quarry	None
Prairie Bluff	Wilcox/AL	Road, Housing, Hydropower	Chinese privet and Japanese honeysuckle
Portland Landing River Slopes	Dallas/AL	Timber harvest, Hydropower	China berrytree, Japanese honeysuckle, and kudzu
Durant Bend	Dallas/AL	Timber harvest	Chinese privet and Japanese honeysuckle
Murphys Bluff Bridge Cahaba River	Bibb/AL	Road with bridge	Chinese privet, Japanese honeysuckle, and others
Creekside Glades and Little Schulz Creek	Bibb/AL	Housing, Utility lines	None
Cottingham Creek Bluff and Pratts Ferry	Bibb/AL	Road with bridge, Timber harvest	Chinese privet and Japanese honeysuckle
Fern Glade and Six Mile Creek	Bibb/AL	Timber harvest	Chinese privet and Japanese honeysuckle
Browns Dam Glade North and South	Bibb/AL	None	Chinese privet
McGuire Ford | Limestone Park	Bibb/AL	Road, Housing, Maintained field	None
Fort Toulouse State Park	Elmore/AL	Maintained field/recreation	Japanese honeysuckle
Fort Gaines Bluff	Clay/GA	Timber harvest	Japanese honeysuckle
Fort Benning (GA) and (AL)	Chattahoochee/GA and Russell/AL	Road	Chinese privet and Japanese honeysuckle
Goat Rock North and South	Harris, Muscogee/GA	Hydropower and Utility lines	Chinese privet and Japanese honeysuckle
Blacks Bluff Preserve	Floyd/GA	Road, Quarry	Napalese browntop and Japanese honeysuckle
Whitmore Bluff	Floyd/GA	Timber harvest	Japanese honeysuckle
Resaca Bluffs	Gordon/GA	Road with bridge, Commercial	Chinese privet and Japanese honeysuckle

Details on surveys for populations of Georgia rockcress throughout its range

Of the 12 populations in Alabama, 6 occur in the Ridge and Valley region (all in Bibb County), and 6 occur in the Coastal Plain region in Dallas (2), Elmore, Wilcox, Monroe and Sumter Counties. Three of the five Georgia populations occur in the Ridge and Valley region (Floyd and Gordon Counties); one occurs in the Piedmont region (Harris/Muscogee Counties); and one occurs in the Coastal Plain region (Clay County). The one population that extends into both States (Russell County, AL/ Chattahoochee County, GA) also occurs below the Fall-line (Allison 1995; Allison 1999; Moffett 2007; Schotz 2010).

During surveys in 1999, Allison (1999) found that populations of this species typically had a limited number of individuals restricted to a small area. Moffett (2007) found approximately 2,140 plants from all known sites in Georgia. In Georgia, Allison (1995) reported that populations had 3 to 63 individuals. However, a 2007 survey, by Moffett (2007), of the six Georgia populations resulted in counts of 5 or fewer plants at one population; 30 to 50 plants at two populations; 150 plants at one population; and two populations (greatly expanded from 1995) of almost 1,000 plants each. In 2009, plants could not be relocated at one Floyd County, Georgia, site, and only one plant was seen at another site where 25 to 50 had been documented in 2007 (Elmore 2010; Garcia 2012). Moffett (2007) indicated that the overall status of the three populations in the Ridge and Valley ecoregion (Floyd and Gordon Counties, Georgia) was poor, as these populations tended to be small and declining in size and vigor. The largest population in Georgia is the multi-site Goat Rock Dam complex in the Piedmont province (Harris/Muscogee Counties) with approximately 1,000 flowering stems at last census (Moffett 2007; Garcia 2012). The Goat Rock Dam population has recently increased by 130%, reflects management efforts to control invasive species by Georgia Power and the Georgia Plant Conservation Alliance. Fort Benning also supports a vigorous population with an estimated 1,000 plants (Moffett 2007; Garcia 2012). Georgia rockcress has been extirpated from its type locality near Omaha, Georgia, in Stewart County (Moffett 2007; Garcia 2012). At another site, Blacks Bluff, Georgia, rockcress had declined to a few individuals by 2007 (Moffett 2007; Garcia 2012), but 100 individuals were replanted in 2009. During a count done in 2013, 31 individuals were found to be surviving at the site, and more than 15,000 seeds were broadcast to supplement this population (Goldstrohm 2013).

Schotz (2010) documented fewer than 3,000 plants from all known sites in Alabama. Populations from Bibb County, Alabama, had between 16 and 229 plants, with 42 and 498 from Dallas County, 47 from Elmore County, 414 from Monroe County, 842 from Russell County, 4 from Sumter County, and 551 from Wilcox County. Allison (1999) originally documented this species at 18 localities (representing seven populations) in Bibb County. However, one of these Bibb County populations was not relocated during surveys in 2001 (Allison 2002, pers. comm.), and plants were not relocated at two other sites in Alabama (Schotz 2010). Therefore, it is believed that Georgia rockcress has been extirpated from these three sites in Alabama.