

FINAL REPORT

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Project Title: Evaluating the Effects of Long-arm Mowing on Virginia Spiraea along US 129 in the Cheoah River Corridor

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16. Abstract Virginia spiraea (<i>Spiraea virginiana</i>) is a rare endemic shrub of the southern Appalachian Mountains. This species has a scattered distribution throughout seven states and is federally listed as Threatened. In North Carolina, <i>S. virginiana</i> is listed as Endangered. <i>Spiraea virginiana</i> is considered an early-successional specialist that occurs along high-gradient streams that regularly flood, but it is also found on right-of-ways that are periodically mowed. The largest population of <i>S. virginiana</i> in North Carolina occurs on U.S. Forest Service (USFS) land adjacent to US 129 in Graham County along the Cheoah River corridor. The North Carolina Department of Transportation (NCDOT) has a right-of-way easement from the USFS along US 129 to control woody vegetation for public safety. Ten of 33 subpopulations of <i>S. virginiana</i> that occur in the Cheoah River corridor are affected by long-arm mowing along US 129. As a result of on-going informal consultations with the U.S. Fish and Wildlife Service (USFWS), NCDOT developed mowing guidelines to help manage and protect these roadside populations. However, the USFWS expressed concern about the potential impacts of long-arm mowing on this species. In response, NCDOT initiated a Biological Assessment to examine the impacts of mowing on <i>S. virginiana</i> along US 129. In 2010, NCDOT awarded the University of North Carolina at Asheville (UNCA) a research grant to develop a study in coordination with NCDOT, USFWS, and the USFS to evaluate the effects of long-arm mowing on <i>S. virginiana</i> along US 129 to supplement the Biological Assessment. The study had a controlled-experimental design, with one dormant-season cutting of <i>S. virginiana</i> by a long-arm mower used as a treatment, and two years of post-treatment monitoring. The study design included grouping subpopulations of <i>S. virginiana</i> into five pairs of treatment and control groups, with the long-arm mowing treatment applied during the winter of 2011. A total of 135 stems (42 in treatment plots, 93 in control plots) growing in the mow zone were tagged in the study plots for monitoring. Of those, 55% of stems in the treatment plots (N = 23) and 29% of stems in the control plots (N = 27) were still alive after two years, representing a 47% difference in the survival rate of <i>S. virginiana</i> (P = 0.004). Total mean length of stems did not differ between treatment and control plots at the beginning of the study (P = 0.11) or at the end of the study (P = 0.31). These results suggest that mowing is beneficial to the viability of <i>S. virginiana</i> growing along roadsides where natural disturbance events are unlikely to occur with any regularity. They also suggest that the effects of mowing on the height of <i>S. virginiana</i> are diminished two years after being cut. Management recommendations for <i>S. virginiana</i> along the US 129 road shoulder include an every-other year mowing regime, periodic cutting of larger trees and shrubs around <i>S. virginiana</i> to maintain a high-light environment, and implementing a monitoring protocol to safeguard against potential long-term mowing effects on this rare species.			
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Executive Summary

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Along US 129 in the Cheoah River Corridor

Executive Summary: Virginia spiraea (*Spiraea virginiana*) is an endemic shrub of the southern Blue Ridge and Appalachian Plateau Physiographic regions. This species has a scattered distribution throughout seven states and is federally listed as Threatened. In North Carolina, *S. virginiana* is listed as Endangered, with only nine populations in the state. *Spiraea virginiana* is considered an early-successional specialist that occurs along riverbanks of high-gradient rocky streams that regularly flood, but it is also found on right-of-ways that are regularly mowed. The largest population of *S. virginiana* in North Carolina occurs on U.S. Forest Service land adjacent to US 129 in Graham County along the Cheoah River corridor. The North Carolina Department of Transportation (NCDOT) has a right-of-way easement from the U.S. Forest Service (USFS) along US 129 to control woody vegetation for public safety. Ten of the 33 subpopulations of *S. virginiana* that occur in the Cheoah River corridor are affected by long-arm mowing along US 129. As a result of on-going informal consultations with the U.S. Fish and Wildlife Service (USFWS), NCDOT developed mowing guidelines to help manage and protect these roadside populations. However, the USFWS expressed concern about the potential impacts of long-arm mowing on this species. In response, NCDOT initiated a Biological Assessment to examine the impacts of mowing on *S. virginiana* along US 129. In 2010, NCDOT awarded the University of North Carolina at Asheville (UNCA) a research grant to develop a study in coordination with NCDOT, USFWS, and the USFS to evaluate the effects of long-arm mowing on *S. virginiana* along US 129 to supplement the Biological Assessment. The study had a controlled-experimental design, with one dormant-season cutting of *S. virginiana* by a long-arm mower used as a treatment, and two years of post-treatment monitoring. The study design included grouping subpopulations (groups of plants occurring together) of *S. virginiana* into five pairs of treatment and control groups, with the long-arm mowing treatment applied during the winter of 2011. A total of 135 stems (42 in treatment plots, 93 in control plots) growing in the mow zone were tagged in the study plots for monitoring. Of those, 55% of stems in the treatment plots ($N = 23$) and 29% of stems in the control plots ($N = 27$) were still alive after two years, representing a 47% difference in the survival rate of *S. virginiana* ($P = 0.004$). Total mean length of stems did not differ between treatment and control plots at the beginning of the study ($P = 0.11$), or at the end of the study ($P = 0.31$). These results suggest that mowing is beneficial to the viability of *S. virginiana* growing along roadsides where natural disturbance events are unlikely to occur with any regularity. They also suggest that the effects of mowing on the height of *S. virginiana* are diminished two years after being cut. Management recommendations include an every-other year mowing regime, periodic cutting of larger trees and shrubs around *S. virginiana* to maintain a high-light environment, and implementing a monitoring protocol to safeguard against potential long-term mowing effects on this rare species.

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Introduction

Virginia spiraea (*Spiraea virginiana*) is a federally threatened shrub that is endemic to the southern Blue Ridge and Appalachian Plateau Physiographic regions (Ogle 1991a, USFWS 1992). In North Carolina, *S. virginiana* is listed as endangered and is found throughout seven mountain counties, including Ashe, Graham, Macon, Mitchell, Swain, Transylvania and Yancey Counties (Robinson and Finnegan 2014). *Spiraea virginiana* is considered an early-successional specialist restricted to a narrowly defined niche, which includes natural disturbance (Ogle 1991a, USFWS 1992). This shrub is most often found along river banks of high-gradient rocky streams that regularly flood, but it also occurs on right-of-ways that are mowed regularly (USFWS 1992). The North Carolina Department of Transportation (NCDOT) currently manages several roadside populations of *S. virginiana* in Ashe and Graham Counties.

The largest known population of *S. virginiana* in North Carolina occurs on U.S. Forest Service (USFS) land along US 129 in Graham County in the Cheoah River corridor (C. Wells, USFWS, pers. com.). The NCDOT has an easement from USFS along US 129 to control roadside woody vegetation for the purpose of public safety. Ten subpopulations of *S. virginiana* occur along the roadside of US 129 and may be affected by long-arm mowing (G. Kaufman, USFS, pers. com.). In 2005, as a result of on-going informal consultations with the U.S. Fish and Wildlife Service (USFWS), NCDOT developed mowing guidelines to help manage and protect these roadside populations. However, because the impacts of mowing this rare plant are not well understood, the USFWS expressed concern about the potential negative impacts of long-arm mowing on *S. virginiana*. As a result, a Biological Assessment (BA) was developed by NCDOT to address the concerns of the USFWS. After review of the BA, the USFWS provided NCDOT with a vegetation management plan which required NCDOT to delineate no-mow zones on the road shoulders of US 129 to protect the subpopulations of *S. virginiana* and to conduct a study to evaluate the effects of dormant season, long-arm mowing on *S. virginiana* (USFWS 2009).

In 2010, NCDOT awarded the University of North Carolina at Asheville (UNCA) a research grant to develop a study in coordination with NCDOT, USFWS, and USFS to evaluate the effects of long-arm mowing on *S. virginiana* along US 129. Herein, we describe the study and the results after two years of monitoring. We also provide recommendations to assist NCDOT in their right-of-way management of *S. virginiana*.

Literature Review

Spiraea virginiana is a rare endemic shrub known from only isolated populations along river corridors in the Southern Appalachians (USFWS 1992). It has a limited range and occurs in only seven states: Georgia, Kentucky, North Carolina, Ohio, Tennessee, Virginia, and West Virginia (USFWS 1992). This species is listed as federally threatened and has a global ranking of G2, or globally imperiled (Robinson and Finnegan 2014). In North Carolina, *S. virginiana* is listed as endangered (Robinson and Finnegan 2014), with

only nine populations occurring in seven western counties, including Ashe, Graham, Macon, Mitchell, Swain, Transylvania, and Yancey (C. Wells, USFWS, pers. commun.). *Spiraea virginiana* was first documented along the Cheoah River in 1940 by H. R. Totten (NCNHP, unpubl. data). However, in that same year this population was considered extirpated because of road building (USFWS 1992). Surveys along the Cheoah River in 1986 indicated that this population was still extirpated (Ogle 1991a), but in 2000, *S. virginiana* was rediscovered along the river (NCNHP, unpubl. data). As of 2013, there were 23 subpopulations of *S. virginiana* along the riparian zone of the Cheoah River (Rossell et al. 2014), and ten subpopulations along the roadside of US 129 affected by long-arm mowing. Threats to *S. virginiana* include habitat loss, alteration of natural flow and disturbance regimes, competition from invasive plants (both native and nonnative species), over-topping by succession, and genetic isolation (USFWS 1992).

Spiraea virginiana is a perennial, rhizomatous shrub in the Rosaceae family that grows 0.5-2.0 m tall (Brzyski and Culley 2011, Kadis 2009). It is considered a disturbance-dependent species that relies almost exclusively on asexual reproduction through vegetative propagation (Anders and Murrell 2001, Ogle 1991b, Potter et al. 2007), although sexual reproduction has been noted by Brzyski and Culley (2011). Its habitat is restricted to scoured areas along high gradient sections of second and third order streams, where periodic flooding maintains its niche by reducing competition from arboreal plants and fast growing herbs and vines (Anders and Murrell 2001, Ogle 1991b, USFWS 1992). Rooting occurs from decumbent stems, rhizomatous growth, or downstream dispersal of root stocks (Anders and Murrell 2001, Ogle 1991b). This species is most often found anchored by rhizomes in the crevices of rocks along stream banks, or in areas of loose deposition such as on rocky bars and shores (Ogle 1991b). It also can creep from stream banks and inhabit edges of disturbed rights-of-ways (Ogle 1991b, USFWS 1992). Beaver (*Castor canadensis*) may aid in the dispersal of *S. virginiana* by leaving fresh cuttings at feeding sites that may be transported downstream for rooting (Rossell et al. 2013).

Regular disturbance is important for the maintenance of *S. virginiana* (Ogle 1991b, USFWS 1992). This plant can persist as a low-growing shrub for decades under the right disturbance conditions (Ogle 1991a, USFWS 1992). Disturbance is thought to reduce competition for light from invading taller trees and shrubs (Ogle 1991b, USFWS 1992). Ogle (1991b) postulates that the probability of extinction of *S. virginiana* increases with low disturbance, which favors plant succession and competition, or by high disturbance, which exceeds levels of population maintenance. *Spiraea virginiana* is a preferred beaver food along the Cheoah River (Rossell et al. 2013), and browsing by beaver may play an important role in the disturbance regime of *S. virginiana* along the Cheoah River by inducing rhizomatous growth (Rossell et al. 2014). Although no studies have examined the effects of mowing *S. virginiana*, Ogle (1991b) speculated that regular right-of-way maintenance along roads may be an inexpensive and effective method for managing *S. virginiana*.

Objectives

The objectives of this study were to evaluate the effects of long-arm mowing on *S. virginiana* along US 129 in the Cheoah River corridor to supplement the Biological Assessment conducted by NCDOT. The study design was developed in coordination with personnel from NCDOT, USFWS, and USFS. The study had a controlled-experimental design, with one dormant-season cutting of *S. virginiana* by a long-arm mower used as a treatment, and two years of post-treatment monitoring.

Study Area

The study area is a 9.2-km section of the Cheoah River along US 129 in Graham County, North Carolina (elevation 390-530 m). This section of river is part of the Cheoah River Floodplain Significant Natural Heritage Area, designated nationally significant because it contains numerous rare plants and animals (Schwartzman 2012), including the largest population of *S. virginiana* in North Carolina (C. Wells, USFWS, pers. commun.). The Cheoah River is a dam-controlled, high-gradient system, with large boulder and pool habitats interspersed with Class III and Class IV rapids (NCDOC 2007). From 1928 to 2005, only minimal flows were maintained in the Cheoah River to maximize production of hydroelectric power (Dilts et al. 2005). In 2005, a more natural flow regime was established to restore the river's ecological communities (Dilts et al. 2005). Current flow rates of the river include monthly base flows of 1.1–2.8 m³s⁻¹ (40–100 cfs) and approximately 20 annual high-flow events that peak around 28 m³s⁻¹ (1000 cfs; FERC 2005). Average annual precipitation of the study area is 167.7 cm, average annual high temperature is 20.3 °C, and average annual low temperature is 6 °C (National Climatic Data Center 2011).

Methods

In spring of 2010, we delineated study plots around ten subpopulations of *S. virginiana* along US 129 that would be affected by long-arm mowing. Boundaries for each plot were located 2.3 m from the outside edge of the furthest *S. virginiana* genet (i.e., clump of *Spiraea* stems < 0.5 m away from the next closet *Spiraea* stem, measured at the base of the plants) of each subpopulation to minimize edge effects between control and treatment plots. Back boundaries of each plot were located 3 m (i.e., width of long-arm mower blade, measured horizontally at road grade using a line level and string) from the road shoulder, thus forming rectangular plots for each subpopulation.

During the spring and summer of 2010, we collected baseline data on the ten subpopulations of *S. virginiana* within each plot. Baseline data included tagging all *Spiraea* genets, measuring the basal diameter of all *Spiraea* stems at a height of 5 cm above the substrate using calipers, measuring the total length of *Spiraea* stems growing above the cut line (i.e., horizontal plane even with the road shoulder that would be cut by a long-arm mower) using a meter tape, and counting the number of corymbs (i.e., cluster

of flowers). Because of the large number of stems that exceeded the cut line within plots, we randomly selected and tagged 10% of the stems that were above the cut line for monitoring purposes, with a minimum of three and a maximum of ten stems tagged per genet.

We paired control and treatment plots based on the similarity of subpopulation size (i.e., total number of *Spiraea* stems within a plot). Within each pair, one plot was cut with a long-arm mower (treatment plot) while the other remained uncut (control plot), and all treatments plots were randomly assigned. See Appendix I for details about subpopulation pairing and locations. During the summer of 2010 and continuing through 2013, the USFS spot-treated all nonnative, invasive species along US 129 corridor which helped to minimize potential confounding factors associated with competitive nonnative plants.

Plots were mowed with a long-arm mower on March 4, 2011. Prior to mowing, boundaries of treatment plots were flagged 2.54 cm below the cut line to help the operator standardize the mowing height among treatment plots. Tagged stems within each plot were then monitored during the summers of 2012 and 2013 using the parameters described above.

Findings and Conclusions

A total of 135 stems (42 in treatment plots, 93 in control plots) were tagged in the study plots for monitoring. Of those, 55% of stems in the treatment plots ($N = 23$) and 29% of stems in the control plots ($N = 27$) were still alive after two years. This represents a 47% difference in the survival rate of *S. virginiana* stems over a two-year period. A Chi-square test indicated that the survival rate of stems was significantly different between treatment and control plots ($\chi^2 = 8.21$, $P = 0.004$), suggesting that mowing had a positive effect on the persistence of *S. virginiana*. This supports Ogle's (1991b) assertions that *S. virginiana* requires disturbance to thrive and that periodic mowing may be an effective method for managing this species in right-of-ways.

Total mean length of stems did not differ between treatment (mean stem length = 181 cm, $SD = 46.0$) and control plots (mean stem length = 190 cm, $SD = 45.5$) at the beginning of our study ($t = 0.96$, $P = 0.11$). Two years after mowing, the total mean length of stems also was not significantly different between treatment (mean = 154 cm, $SD = 36.0$) and control plots (mean = 176 cm, $SD = 30.0$; $P = 0.31$). However, it should be noted that mowed stems on average were 22 cm (approximately 9 inches) shorter than unmowed stems. Although total stem length does not translate directly into total height of *Spiraea* plants because many of the stems do not stand erect, stem length may be used as a relative index of plant height. Therefore, the findings above suggest that *S. virginiana* plants generally are able to recover most of their height two years after being mowed.

We found that basal stem diameter was not a reliable measurement for evaluating growth patterns of *S. virginiana*. It was evident that there was unusually high variability in the diameter measurements of individual stems among years. Although we attempted to

standardize the basal diameter measurements by measuring stems 5 cm above the substrate, this proved difficult because of the variability associated with determining the bottom of the substrate, as many of the stems originated from deep fissures between rocks. Furthermore, field observations suggest that basal diameters of *Spiraea* stems did not appreciably increase over the two-year study period.

Results of this study suggest that mowing is beneficial to the viability of *S. virginiana* growing along roadsides where natural disturbance events are unlikely to occur with any regularity. This is supported from the finding that the survival rate of mowed stems was significantly higher than unmowed stems. In addition, results suggest that the effects of mowing on the height of *S. virginiana* plants are essentially diminished two years after being cut. This is supported by the finding that mean total length of mowed stems did not differ from that of unmowed stems two years after mowing. These results, however, should be viewed with caution because of the study's limited sample size and short duration, and because some of the *S. virginiana* had been browsed by beaver during the study. We suggest that a longer-term study is needed using *Spiraea* genets as the unit of replication in the study design, which would increase the sample size and allow evaluation of a variety of treatment factors over a longer period of time. We also suggest that some *Spiraea* genets be fenced in order to exclude the potential confounding effects of beaver in the study.

Management Recommendations

Based on our research and field observations, we believe that periodic mowing is important for maintaining the health and vigor of *S. virginiana* that grow along roadsides where regular natural disturbance events are less likely to occur. Based on our study results, an every-other-year mowing regime may be adequate for maintaining the vigor of *S. virginiana* as well as for ensuring that their height does not impede visibility along US 129 and create a potential safety hazard. Periodic cutting of larger trees and shrubs around the *S. virginiana* plants is also recommended to help maintain a high-light environment which this species prefers (Ogle 1991b, USFWS 1992, Horton et al., in review). We also suggest that a simple monitoring protocol for *S. virginiana* be incorporated into any roadside management plan, because the long-term effects of mowing are unknown.

Implementation and Technology Transfer Plan

Undergraduate Research Reports

Kathryn Selm. 2011. Use and availability of the federally-threatened Virginia Spiraea (*Spiraea virginiana*) by the American beaver. Journal of Undergraduate Research, University of North Carolina at Asheville, Asheville, NC.

Margot Wallston. 2011. Microhabitat of the federally threatened *Spiraea virginiana* along the Cheoah River in North Carolina. Journal of Undergraduate Research, University of North Carolina at Asheville, Asheville, NC.

Scott Arico. 2012. Assessment of beaver browsing on the federally-threatened Virginia Spiraea (*Spiraea virginiana*) along the Cheoah River, North Carolina. Journal of Undergraduate Research, University of North Carolina at Asheville, Asheville, NC.

Joseph McKenna. 2012. Habitat characteristics of *Spiraea virginiana* Britton, an imperiled riparian shrub. Journal of Undergraduate Research, University of North Carolina at Asheville, Asheville, NC.

Kristin Emery 2013. Effects of open pollination, selfing, inbreeding, and outbreeding treatments on seed set and viability in *Spiraea virginiana* Britton (Virginia Spiraea), an endangered rose.

Professional Presentations

Kathryn Selm, C. Reed Rossell, Jr., H. David Clarke, Jonathan L. Horton, and Jennifer Rhode-Ward. 2011. Use and availability of the federally-threatened Virginia Spiraea (*Spiraea virginiana*) by the American beaver. Poster presentation. 72nd Annual Meeting of the Association of Southeast Biologists. Huntsville, AL. April 2011.

Margot Wallston, C. Reed Rossell, Jr., H. David Clarke, Jennifer Rhode Ward, and Jonathan L. Horton. Microhabitat of the federally threatened *Spiraea virginiana* along the Cheoah River in North Carolina. Poster presentation. 72nd Annual Meeting of the Association of Southeast Biologists. Huntsville, AL (Best Student Poster Award, Southern Appalachian Botanical Society). April 2011.

Scott Arico, C. Reed Rossell, Jr., H. David Clarke, Jonathan L. Horton, and Jennifer Rhode Ward. Assessment of beaver browsing on the federally-threatened Virginia Spiraea (*Spiraea virginiana*) along the Cheoah River, North Carolina. Poster presentation. 73rd Annual Meeting of the Association of Southeast Biologists. Athens, GA. April 2012.

Joe McKenna, Jonathan L. Horton, C. Reed Rossell, Jr., H. David Clarke, and Jennifer Rhode Ward. Habitat characteristics of *Spiraea virginiana* Britton, an imperiled riparian shrub. Poster presentation. 73rd Annual Meeting of the Association of Southeast Biologists. Athens, GA. April 2012.

Kristin Emery, Jennifer Rhode Ward, and H. David Clarke. Effects of open pollination, selfing, inbreeding, and outbreeding treatments on seed set and viability in *Spiraea virginiana* Britton (Virginia Spiraea), an endangered rose. Poster Presentation. 75th Annual Meeting of the Association of Southeast Biologists. Spartanburg, SC. April 2014.

Peer-reviewed Publications

Rossell, C.R., Jr., K. Selm, H.D. Clarke, J.L. Horton, J. Rhode Ward, and S.C. Patch. 2013. Impacts of beaver foraging on the federally-threatened Virginia spiraea (*Spiraea virginiana*) along the Cheoah River, North Carolina. *Southeastern Naturalist* 12: 439-447.

Rossell, C.R., Jr., S. Arico, H.D. Clarke, J.L. Horton, J. Rhode Ward, and S.C. Patch. 2014. Forage selection of native and nonnative woody plants by beaver in a rare-shrub community in the Appalachian Mountains of North Carolina. *Southeastern Naturalist* 13:649-662.

Horton, J.L., McKenna J., C.R. Rossell Jr., H.D. Clarke, J. Rhode Ward, and S.C. Patch (in review). Habitat characteristics of *Spiraea virginiana* Britton, a threatened riparian shrub, in North Carolina (Submitted to *Castanea*).

Literature Cited

Anders, C.M., and Z.E. Murrell. 2001. Morphological, molecular, and biological variation within the imperiled Virginia Spiraea. *Castanea* 66:24-41.

Brzyski, J.R., and T.M. Culley. 2011. Genetic variation and clonal structure of the rare, riparian shrub *Spiraea virginiana* (Rosaceae). *Conservation Genetics* 12:1323–1332.

Dilts, E., P. Leonard, and D. Hill. 2005. Development of an integrated flow regime recommendation for the Cheoah River, NC. Proceedings of the 2005 Georgia Water Resources Conference. K.J. Hatcher, ed., Institute of Ecology, University of Georgia, Athens, GA.

Federal Energy Regulatory Commission (FERC). 2005. Tapoco Hydroelectric Project (FERC No. 2169), Cheoah River bypassed reach gravel enhancement plan. Alcoa Power Generating, Tapoco Division, Badin, NC. 9pp.

Horton, J.L., McKenna J., C.R. Rossell, Jr., H.D. Clarke, J. Rhode Ward, and S.C. Patch (in review). Habitat characteristics of *Spiraea virginiana* Britton, a threatened riparian shrub, in North Carolina (submitted to *Castanea*).

Kadis I. 2009. *Spiraea virginiana*. Center for Plant Conservation National Collection Plant Profile.
http://www.centerforplantconservation.org/collection/cpc_viewprofile.asp?CPCNum=4076.

Ogle, D.W. 1991a. *Spiraea virginiana* Britton: I. Delineation and distribution. *Castanea* 56:287-296.

- Ogle, D.W. 1991b. *Spiraea virginiana* Britton: II. Ecology and species biology. *Castanea* 56:297-303.
- National Climatic Data Center. 2011. Annual precipitation and temperatures, Robbinsville, NC. Available online at <http://www.ncdc.noaa.gov/oa/climate/climatedata.html>. Accessed December 2011.
- North Carolina Department of Commerce (NCDOC). 2007. The Cheoah River, Graham County, NC (brochure). Graham County Travel and Tourism Authority, Robbinsville, NC. 2pp.
- Potter, D., S.M. Still, T. Grebenc, D. Ballian, G. Bozic, J. Franjiae, and H. Kraigher. 2007. Phylogenetic relationships in tribe Spiraeae (Rosaceae) inferred from nucleotide sequence data. *Plant Systematics and Evolution* 266:105-118.
- Robinson, L. G., and J. T. Finnegan. 2014. Natural Heritage Program List of Rare Plant Species of North Carolina. 2014. North Carolina Natural Heritage Program, Division of Parks & Recreation, NC Department of Environment, Health, and Natural Resources, Raleigh, NC. 140 pp.
- Rossell, C.R., Jr., K. Selm, H.D. Clarke, J.L. Horton, J. Rhode Ward, and S.C. Patch. 2013. Impacts of beaver on the federally-threatened Virginia Spiraea (*Spiraea virginiana*) along the Cheoah River, North Carolina. *Southeastern Naturalist* 12:439-447.
- Rossell, C.R., Jr., S. Arico, H.D. Clarke, J.L. Horton, J. Rhode Ward, and S.C. Patch. 2014. Forage selection of native and nonnative woody plants by beaver in a rare-shrub community in the Appalachian Mountains of North Carolina. *Southeastern Naturalist* 13:649-662.
- Schwartzman, E. 2012. Site survey report: Cheoah River floodplain (unpublished). North Carolina Heritage Program, Division of Parks & Recreation, NC Department of Environment, Health, and Natural Resources, Raleigh, NC. 2pp.
- U.S. Fish and Wildlife Service (USFWS). 2009. Letter to NCDOT: Proposed Vegetation Management Plan for the Cheoah River Corridor, Nantahala National Forest, Graham County, North Carolina. U.S. Fish and Wildlife Service, Asheville Field Office, Asheville, NC. 5 pp.
- U.S. Fish and Wildlife Service (USFWS). 1992. Virginia spiraea (*Spiraea virginiana* Britton) Recovery Plan. Newton Corner, Newton, MA. 47 pp.

Appendix I. Experimental pairing details and GPS coordinates of subpopulations of *S. virginiana* used in the mowing study along US 129, Graham County, NC, 2011-2013.

Pair	Subpopulation	Treatment	GPS Coordinates	
			Latitude	Longitude
1	2-1	mow	35.424329	83.904886
	12-2	control	35.397682	83.871530
2	12-5	mow	35.398043	83.870529
	10-2	control	35.401759	83.881895
3	12-7	mow	35.398228	83.870062
	12-4	control	35.397822	83.871111
4	10-3	mow	35.401706	83.881813
	3-2	control	35.425011	83.898609
5	12-3	mow	35.397769	83.871330
	3-1	control	35.424903	83.898788

Appendix II. List of undergraduate students participating in the *S. virginia* research project.

Scott Arico	M.S. Student, Biology, Eastern Kentucky University
Gwen Casebeer	Ph.D. Student, Biology, UC-Santa Cruz
Kristin Emery	Laboratory Assistant, Sequenom Inc.
David Greene	Guide, Navitat
Karissa Keen	
Samantha Maser	Staff, Best Buy
Joseph McKenna	M.S. Student, Biology, Appalachian State University
Megan Rayfield	AmericaCorps Stewardship Association, Carolina Mountain Land Conservancy
Robert Rives	
Mathew Searels	CN Utility Consulting, Sebastopol, CA
Kathryn Selm	M.S. Student, Urban Ecology, NC State University
Margot Wallston	Southern Appalachian Highlands Conservancy
Andrew Watson	Ph.D. Student, Mathematical Biology, University of Utah
