THE DEVELOPMENT OF A DATA DRIVEN MANAGEMENT PLAN FOR THE TATER HILL PLANT PRESERVE

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by
BYRON L. BURRELL

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APPROVED BY:

Matt C. Estep
Chairperson, Thesis Committee

Zachary J. Farris
Member, Thesis Committee

Steven W. Seagle
Member, Thesis Committee

Michael D. Madritch
Member, Thesis Committee

Zack E. Murrell
Chairperson, Department of Biology

Michael McKenzie, Ph.D.
Dean, Cratis D. Williams School of Graduate Studies

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Abstract

THE DEVELOPMENT OF A DATA DRIVEN MANAGEMENT PLAN
FOR THE TATER HILL PLANT PRESERVE

Byron Burrell
B.S., Appalachian State University
M.S., Appalachian State University

Chairperson: Matt C. Estep

The Tater Hill Plant Preserve was established to protect rare and state-endangered plant species and their habitats. The acquisition and management of plant habitats have successfully increased population growth and limit external negative anthropogenic effects. This study demonstrates the importance of assessing biotic threats to rare plant populations and determining future actions to promote conservation management decisions. Trail camera technology was used to determine vertebrate occurrence, species richness, species composition, daily activity levels, and vertebrate movement patterns within the Tater Hill Plant Preserve. In addition, a microsatellite assessment of the invasive species *Centaurea maculosa*, commonly known as Spotted Knapweed found allelic richness and heterozygosity indicative of a founders effect with multiple introduction to the Tater Hill Plant Preserve. Finally, geographic information systems was used to create range distribution maps that update current locality data and can support future land management decisions. This study is a multidisplinary method to understand how vertebrates and invasive species

are using the Tater Hill Plant preserve, and contributes to the protection and growth of rare plant populations in the Tater Hill Plant Preserve. These methods can be used to advance conservation practices across plant preserves around the state.

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Foreword

Chapter Two of this thesis will be submitted to Journal of Wildlife Management, an international peer-reviewed journal owned by The Wildlife Society and published by John Wiley & sons, Inc.; it has been formatted according to the style guide for that journal.

Chapter Three of this thesis will be submitted to Southeastern Naturalist, a regional peer-reviewed journal owned by Eagle Hill Institute and published by Eagle Hill Publications; it has been formatted according to the style guide for that journal.

Chapter One – Rare and Endangered Plants of the Tater Hill Plant Preserve

A History of Tater Hill

Tater Hill is a mountainous area located in northwestern Watauga County, NC. The Tater Hill tract was owned by the Federal Land Bank in the late 1930s when a local interest group named Tater Hill Inc. purchased the property (Flisser 1979). The focus of Tater Hill Inc. was to create a resort community, and they contracted the Alexander Construction Company to create an artificial lake for recreational use. Within a year of completion, the artificial lake was destroyed when the earthen dam washed out due to heavy rains. In the summer of 1940, the Alexander Construction Company built a more stable structure using a concrete spillway measuring four feet wide and six feet deep, and it included an eighteen-inch drainpipe at the base (Flisser 1979).

The construction of the second dam was completed in 1940, but the resort community was placed on hold due to the washout of the first dam and the escalation of World War II. This delay eventually caused the cancelation of the resort community altogether, and in 1969, a 1,245 acre tract of land was purchased by Rich Mountain Associates. The lake continued to be used by local residents for recreational activities.

Between the dates of November 2nd and 6th of 1977, approximately 33.30 cm of rain fell in the Tater Hill area. At approximately 9:30 in the morning of the 6th, the Tater Hill Lake dam failed, allowing a washout to occur down Howard's Creek and the surrounding area (Flisser 1979). Several homes, house trailers, and farm structures were destroyed. The

lake completely drained during this event, allowing the natural high elevation bog that once inhabited the area to reestablish itself.

Since the dam broke in 1977, two studies have looked at the diversity of plant life that exists within the Tater Hill area. The first study documented the successional invasion of plants into the old lakebed and determined species richness in and near the empty lakebed (Flisser 1979). The second study investigated the vascular plant diversity of the entire Tater Hill Mountain, identifying 94 plant families and 471 plant species (Martin 2007). These surveys informed land managers of the overall diversity while also showing evidence of rare plants within the area.

Creation of the Tater Hill Plant Preserve

The old Tater Hill lake basin was recorded at eight acres in size and was one of the first areas protected within the Tater Hill Plant Preserve. The lake basin and surrounding forest parcel of 158.57 acres was purchased by collaboration between the Plant Conservation Program (PCP), a part of the North Carolina Department of Agricultures and Consumer Services, the Trust for Public Land, and the Natural Heritage Trust Funds on August 25th, 2000. The Tater Hill Plant Preserve has grown to approximately 1,200 acres over the last seventeen years with the purchase of surrounding parcels. The Preserve is expected to grow by another 369 acres over the next few years with the purchase of Harmon Knob and other smaller parcels ("Conservancy buys Harmon Knob property" 2016).

The Tater Hill Plant Preserve currently contains the headwaters to Howard's Creek, and, with the addition of Harmon Knob, a tributary of Norris Fork. These watersheds protect the drinking water for Boone, the surrounding area, as well as communities along the New River north of Watauga County.

Elevation within The Tater Hill Plant Preserve ranges between 1,082 meters (3,550 feet) at the base of the old dam to 1,644 meters (5,393 feet) at the top of Rich Mountain Bald, and it includes a variety of habitats throughout the property. These include High Elevation Rock Outcrops, Grassy Bald, High Elevation Red Oaks forests, High Elevation bogs and seeps, Northern Hardwood forests with a variety of sub-types, and a few other minor habitat types. The preserve stretches for roughly 5.6 km (3.48 miles) at its longest and 1.52 km (0.94 miles) at its widest (figure 1). The preserve has a few designated maintenance roads with several old logging paths used for walking trails by management and recently had gates placed throughout the preserve to reduce vehicle access.

Materials and Methods for Current Plant Surveys

Currently, 25 species found on the preserve are either state listed at threatened (extant and historical records) or rare (but not federally listed species) (Table 1.). This list was used to generate phenology charts to predict flowering time, along with rudimentary field guides to assist in field identification. In addition, the PCP provided georeferenced shapefiles for some of these species. Each shapefile represented the area of coverage by individual patches of a species of concern within the preserve. Plant species with georeferenced patch information included *Micranthes pensylvanica* (Linnaues) Hawthorn, *Ilex collina* Alexander, *Packera schweinitziana* Nuttall W.A. Weber & A. Love, *Carex trisperma* Dewey, *Lilium grayi* S. Watson, *Lilium philadelphicum* Linnaeus, *Platanthera grandiflora* (Bigelow) Lindley, *Geum geniculatum* Michaux, and *Delphinium exaltatum* Aiton.

Plants were found using modified wandering surveys (Kell 2006). These surveys typically relied on finding the path of least resistance between trail cameras placed in various

locations across the preserve. When georeferenced locality data was provided, patches were evaluated for the number of flowering individuals in the population, or estimates of the area were calculated, and new ArcGIS shapefiles were created to establish current patch size. These shapefiles were created by standing near plants on the outside perimeter of the patch and marking a waypoint using a Garmin 64st, Garmin 550t, or Garmin 750t GPS unit (Garmin, Olathe, Kansas, USA). Waypoint data was then imported into Garmin Basecamp software (4.6.2), exported as a gpx file, and then loaded into ArcMap (10.3.1). Once multiple waypoints had been placed around the perimeter of a patch, waypoints were used as vertex locations, and then the polygon features tool was used to construct new shapefiles. A shapefile name was created based on the species of interest. Once a new shapefiles was created it was compared to pre-2016 distributions by calculating area using the measure tool of ArcGIS. The increase or decrease in area will be reported per individual species and as a total protected habitat gained or lost since pre-2016 surveys.

Results for Individual Species

Aconitum reclinatum

Aconitum reclinatum A. Gray, Ranunculaceae is commonly referred to as Trailing White Monkshood. This herbaceous perennial plant with a green and white flower has been reported on the preserve (Kong, et al. 2017). It is easiest to identify when it blooms from June to September each year. *Aconitum reclinatum* is not considered rare, but it has a G3/S3 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G3 means that *Aconitum reclinatum* populations are vulnerable, typically having between 21 and 100 occurrences around the globe, or between 3,000 to 10,000 individuals. North

Carolina ranks *Aconitum reclinatum* as a S3, which refers to vulnerable populations with typical occurrence ranging from 21 to 100 and populations between 3,000 and 10,000 individuals remaining in the state. It is also considered a national wetland plant (Kintsch and Urban 2002, Robinson and Finnegan 2016). During the 2017 field season, *Aconitum reclinatum* was not identified in any of our surveys on the Tater Hill Plant Preserve, but the conservation stewards are aware of at least one population (per. Comm. Estep).

Cardamine clematitis

Cardamine clematitis Shuttleworth ex A. Gray Brassicaceae is commonly referred to as Small Mountain Bittercress. This herbaceous perennial plant with a white flower has been reported on the preserve (Robinson and Finnegan 2016). It is more commonly found in high elevation sites above 1,200 m, prefers stream banks or seeps, and blooms from April to May each year (Gaddy 2014, Weakley 2015). *Cardamine clematitis* is considered rare, but it has a G3/S2-S3 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G3 means that *Cardamine clematitis* populations are vulnerable, typically having between 21 and 100 occurrences around the globe, or between 3,000 and 10,000 individuals. The North Carolina ranking is uncertain, with its status remaining between S2 and S3, denoting imperiled or vulnerable populations having between 6 to 100 occurrences across the state and individual estimates ranging from 1,000 to 10,000 individuals in the state. *Cardamine clematitis* populations were found during the 2017 surveys within the Tater Hill Plant Preserve. An estimated population of 88 flowering individuals with significant numbers of vegetative individuals spread over approximately 3.19 hectares (7.91 acres) (Figure 2). Individuals were interspersed amongst moss-covered rocks located within a northern

hardwood forest community (Birch Boulder Field and Beech gap sub-types). There were no game trails moving through these populations, and patches were surrounded by *Acer spicatum* (Mountain Maple), *Fagus grandifolia* (American Beech), and *Betula alleghaniensis* (Yellow Birch). These individuals were reproductive, and seed production was observed. Locality and site community information was documented and reported to the North Carolina Natural Heritage Program along with updated GPS coordinates.

Carex baileyi

Carex baileyi Britton, Cyperaceae is commonly referred to as Bailey's Sedge. This perennial sedge is known as an obligate wetland species in the Eastern Mountains and Piedmont of North America. *Carex baileyi* is more frequently found in bogs and seeps and commonly blooms from June to July each year (USDA 2015, Weakley 2015). *Carex baileyi* is uncommon, but it has a conservation status of G3-G4/S2 globally and in North Carolina (Robinson and Finnegan 2016). Globally, G3/G4 denotes an inexact numeric rank referring to *Carex baileyi* as typically having between 21 and greater than100 occurrences around the globe, or between 3,000 and greater than 10,000 individuals. North Carolina ranks *Carex baileyi* as a S2 referring to an imperiled population with typical occurrence ranging from 6 to 20 occurrences and between 1,000 and 3,000 individuals remaining in the state. During the 2017 field season, *Carex baileyi* was not identified in any of our surveys on the Tater Hill Plant Preserve.

Carex roanensis

Carex roanensis F.J. Hermann, Cyperaceae is commonly referred to as Roan Mountain Sedge. This perennial sedge is characterized by sheathing bracts, linear spikes, and pubescent leaves (Smith and Waterway 2008). It is easiest to identify when it blooms from May to June each year. *Carex roanensis* is rare, but it has a conservation status of G2-G3/S2 globally and in North Carolina (Robinson and Finnegan 2016). When found, *C. roanensis* shows habitat preferences for cove forests, moderate to high elevation oak forests, and northern hardwood forests (Weakley 2015). Globally, G2-G3 denotes an inexact numeric rank, which refers to *Carex roanensis* as typically having between 6 and 100 occurrences around the globe, or between 1,000 and 10,000 individuals. North Carolina ranks *Carex roanensis* as a S2, which refers to imperiled populations with typical occurrences ranging from 6 to 20 individuals, and between 1,000 and 3,000 individuals remaining in the state. During the 2017 field season, *Carex* roanensis was not identified in any of our surveys on the Tater Hill Plant Preserve.

Carex trisperma

Carex trisperma Dewey, Cyperaceae is commonly referred to as Three-seeded Sedge (USDA 2015). This perennial sedge is known as an obligate wetland species in the Eastern Mountains and Piedmont of North America. *Carex trisperma* is more frequently found in bogs, seeps, and swamps at high elevations (Weakley 2015). It is easiest to identify when it blooms in June each year. When found *C. trisperma* shows habitat preferences of living in *Sphagnum*, usually found in shaded areas under shrubs or trees in montane wetlands. *Carex trisperma* is rare and state listed, but it has a conservation status of G5 globally, and S1

(endangered status) in North Carolina (Robinson and Finnegan 2016). Globally, G5 denotes a species as being common or widespread, typically having considerably more than 100 occurrences and more than 10,000 individuals remaining. North Carolina ranks *Carex trisperma* as a S1, which refers to critically imperiled populations with typical occurrences being 5 or fewer, and number of individuals being 1,000 or fewer in the state. During the 2017 field season, *Carex trisperma* was not identified in any of our surveys on the Tater Hill Plant Preserve.

Carex woodii

Carex woodii Dewey, Cyperaceae is commonly referred to as Wood's Sedge. This perennial sedge is known as an obligate upland species in the Eastern Mountains and Piedmont of North America, almost never occurring in wetlands as reported by the USDA. (USDA 2015). However, Weakly reports that *Carex woodii* is more frequently found on moist slopes and cove forests over mafic rocks similar to amphibolite (Weakley 2015). It is easiest to identify when it blooms from May to June each year. *Carex woodii* is known as significantly rare and only the peripheral of its range exists in North Carolina (Robinson and Finnegan 2016). *Carex woodii* has a G4/S3 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G4 means that *Carex woodii* populations are apparently secure, typically having more than 100 occurrences around the globe, or greater than 10,000 individuals. North Carolina ranks *Carex woodii* as a S3, which refers to vulnerable populations with typical occurrences ranging from 21 to 100 and between 3,000 and 10,000 individuals remaining in the state. During the 2017 field season, *Carex woodii* was not identified in any surveys on the Tater Hill Plant Preserve.

Chelone cuthbertii

Chelone cuthbertii Small, Plantaginaceae is commonly referred to as Cuthbert's Turtlehead. This perennial herb is known as an obligate wetland species in the Eastern Mountains and Piedmont of North America, almost always occurring in wetlands (USDA 2015). It is more frequently found in bog, sphagnous swamps, and seeps (Weakley 2015). It is easiest to identify when it blooms from July to September each year. *Chelone cuthbertii* is uncommon, but it has a G3/S3 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G3 means that *Chelone cuthbertii* populations are vulnerable typically having between 21 and 100 occurrences around the globe, or between 3,000 to 10,000 individuals. North Carolina ranks *Chelone cuthbertii* as a S3, which refers to vulnerable populations with typical occurrences ranging from 6 to 20 and between 3,000 and 10,000 individuals remaining in the state. During the 2017 field season, individuals within the *Chelone* genus were identified on the Tater Hill Plant Preserve, but individuals were not identified to the species level. These areas will be prioritized in future population surveys to verify the species (Figure 3).

Chelone obliqua

Chelone obliqua Linnaeus, Plantaginaceae is commonly referred to as Purple Turtlehead. This perennial herb is known as an obligate wetland species in the Eastern Mountains and Piedmont of North America almost always occurring in wetland habitats (USDA 2015). It is more frequently found around stream banks, and swamp forests (Weakley 2015). It is easiest to identify when it blooms from July to October each year. *Chelone obliqua* is rare across its range, but it has a G4/S2 conservation status globally and

in North Carolina (Robinson and Finnegan 2016). Globally, G4 means *Chelone obliqua* populations are apparently secure, typically having more than 100 occurrences around the globe, or greater than 10,000 individuals. North Carolina ranks *Chelone obliqua* as a S2, which refers to imperiled populations with typical occurrences ranging from 6 to 20 and between 1,000 and 3,000 individuals remaining in the state. During the 2017 field season, individuals within the *Chelone* genus were identified on the Tater Hill Plant Preserve, but individuals were not identified to the species level. These areas will be prioritized in future population surveys to verify the species (Figure 3).

Corallorhiza maculate var. maculate

Corallorhiza maculate var. maculate Rafinesque, Orchidaceae is commonly known as Eastern Spotted Coralroot. It is more frequently found around moist forests and northern hardwood forests (Weakley 2015). It is easiest to identify when it blooms in July each year. *Corallorhiza maculate var. maculate* is uncommon, but it has a G5-T5/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5-T5 means the subspecies *Corallorhiza maculate var. maculate* or variety populations are secure, and typically have considerably more than 100 occurrences around the globe, and greater than 10,000 individuals. North Carolina ranks *Corallorhiza maculate var. maculate* as a S2, which refers to imperiled populations with typical occurrences ranging from 6 to 20 and between 1,000 and 3,000 individuals remaining in the state. During the 2017 field season, *Corallorhiza maculate var. maculate* was not identified in any of our surveys on the Tater Hill Plant Preserve.

Delphinium exaltatum

Delphinium exaltatum Aiton, Ranunculaceae is commonly known as Tall Larkspur. It is more frequently found in a spectrum of dry to wet soils over mafic rocks and can grow in open grassy bald habitats or forest edges in partial sun (Weakley 2015). It is easiest to distinguish when it blooms from August to September, where it presents pale to medium blue flowers (Weakley 2015). *Delphinium exaltatum* is rare across its range, but it has a G3/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G3 means that *Delphinium exaltatum* populations are vulnerable, typically having between 21 and 100 occurrences around the globe, or between 3,000 and 10,000 individuals. North Carolina ranks *Delphinium exaltatum* as a S2, which refers to imperiled populations with typical occurrences ranging from 6 to 21 and populations between 1,000 and 3,000 individuals remaining in the state. During the 2017 field season, *Delphinium exaltatum* was identified within the Tater Hill Plant Preserve. Surveys produced an approximate population count of 1301 flowering individuals spread over a total of 1.01 hectares (2.49 acres). The *Delphinium exaltatum* population was divided into two separate patches with approximately 134.77 meters between patches. Patch 1 (lower slope) had approximately 900 individuals spread out across 0.86 hectares (2.11 acres), while Patch 2 (upper slope) had approximately 401 individuals spread out across 0.15 hectares (0.38 acres). This is an area decrease of 2.12 hectares (3.07 acres) compared to coordinate data previously recorded by PCP (Figure 4). The entire population was located within the grassy bald habitat of the Tater Hill Plant Preserve. Using the Natural Heritage Rare Plant Survey Form, population viability is rated as good with potential concerns of population viability pertaining to game trails moving throughout *Delphinium* patches and frequent trespasser occurrence.

Geum geniculatum

Geum geniculatum Michaux, Rosaceae is commonly referred to as Bent Avens. This perennial herb is more frequently found in wet habitats such as those within seeps, seep like boulderfield forests, grassy balds, cliff basses, and banks of streams up to 5 m wide (Weakley 2015). It is easiest to distinguish when it blooms from late June to August. *Geum geniculatum* is rare, but it has a G2/S1-S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G2 means that *Geum geniculatum* populations are imperiled, typically having between 6 and 21 occurrences around the globe, or between 1,000 and 3,000 individuals. North Carolina ranking is uncertain with status remaining between S1 and S2 denoting critically imperiled or imperiled populations being between 1 and 20 occurrences across the state with individual estimates ranging from less than 1,000 to 3,000 individuals remaining in the state. During the 2017 field season, *Geum geniculatum* was identified within the Tater Hill Plant Preserve. Surveys produced an approximate population of around five individuals spread out over 0.05 hectares (0.11 acres). *Geum geniculatum* was divided into three separate patches, with approximately 245.86 meters being the closest distance between any two patches. Patch 1 (lowest elevation) was confirmed to have *Geum geniculatum* vegetative individuals spread over approximately 0.07 hectares (0.17 acres) but no flowering structures. Patch 2 (mid-slope) had two flowering individuals spread over approximately 0.02 hectares (0.04 acres). Patch 3 (upper slope) had approximately three individuals flowering with other vegetative individuals spread across 0.03 hectares (0.07 acres). Compared to previous records, this is an area decrease of 0.88 hectares (2.05 acres) (Figure 5). Patch 1 was identified in the center of an actively use motorized roadbed with a significant number of vegetative individuals, but no flowering structures or fruits bodies were

observed. Conservation stewards have gated off trails to decrease motorized activity in this area. Patch 2 was identified in the grassy bald near an exposed rock outcrops. Population viability concerns involve encroaching shrubbery such as *Rhododendron calendulaceum* (Flame Azalea), and *Vaccinium angustifolium* (Lowbush Blueberry), along with active game trails moving through the site. Patch 3 was identified on the edge of a small grassy bald (# 3) surrounded by a Crataegus forest type. Population viability concerns derive from recreation use of an illegal hiking trail coming directly through the site. Conservation stewards have since marked boundaries; closed advertising websites of illegal trail location and employed trail cameras to assist with population monitoring.

Ilex collina

Ilex collina Alexander, Aquifoliaceae is commonly referred to as Long-stalked Holly or Cherry Holly. This perennial shrub is frequently found in peats of bogs, seepages and on the banks of high elevation streams (Weakley 2015). It is easiest to identify when it blooms from May to June. *Ilex collina* is rare across its range, and it has a G3/S1 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G3 means that *Ilex collina* populations are vulnerable, typically having between 21 and 100 occurrences around the globe, or between 3,000 and 10,000 individuals. North Carolina ranks Ilex collina as a S1, which refers to a critically imperiled population with typical occurrence being 5 or fewer, and number of individuals being 1,000 or fewer remaining in the state. During the 2017 field season, *Ilex collina* was not identified in any of our surveys on the Tater Hill Plant Preserve, but the conservation stewards are aware of at least one population (per. Comm. Estep).

Lilium grayi

Lilium grayi S. Watson, Liliaceae is commonly referred to as Gray's Lily. This herbaceous perennial herb is more frequently found in bogs, seeps, grassy balds, moist forests and wet meadows between medium to high elevation (Weakley 2015). It is easiest to identify when it blooms from June to July, when it presents an orange or red flower said to be one of the most beautiful flowers of the Mid-Atlantic states (Weakley 2015). *Lilium grayi* is rare across its range, and it has a G3/S3 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G3 means that *Lilium grayi* populations are vulnerable, typically having between 21 to 100 occurrences around the globe, or between 3,000 and 10,000 individuals. North Carolina ranks *Lilium grayi* as a S3, which refers to vulnerable populations with typical occurrences ranging from 6 to 20 individuals and between 3,000 and 10,000 individuals remaining in the state. During the 2017 field season, *Lilium grayi* was identified within the Tater Hill Plant Preserve.

Lilium grayii is one of the most charismatic plants inhabiting the preserve and is monitored more closely than other plant species. The single elemental occurrence is broken into 20 patches across the preserve. The largest distance between any two patches being approximately 3.35 kilometers (2.08 miles) and the shortest distance between two patches being 45.58 meters (Figure 6). Due to the extensive number of patches and variety of locations, *Lilium grayi* surveys were conducted in a different method then other rare plants within the Tater Hill Plant Preserve. Prior *Lilium grayi* patches data was uploaded to Garmin 64st handheld GPS units and then individual patches were surveyed for flowering individuals following PCP protocol. The number of individual patches were recorded along with population viability concerns and GPS coordinates.

Patch 1 had no vegetative or flowering individuals of *Lilium grayi* across approximately 0.2 hectares (0.4 acres). Patch 1 is located on private property just off the Tater Hill Plant Preserve (Figure 7). Population viability is estimated to be low. Concerns consist of suitable habitat being found but no evidence of Gray's Lily existing within Patch 1. If Patch 1 is surveyed again and found to have no *Lilium grayi* it would represent a 0.2 hectare (0.4 acre) decrease in *Lilium grayi* area within the Tater Hill Plant Preserve.

Patch 2 was surveyed and found to have two flowering individuals spread across approximately 0.03 hectares (0.08 acres). Patch 2 is located just north of the Tater Hill Bog (Figure 7). Population viability concerns consist of encroaching *Rhododendron spp* (Rhododendrons). *Lilium grayi* was limited to pockets where Rhododendrons thinned enough to allow light through the canopy. These pockets were typically small averaging less than two square feet. Previous coordinate data listed an area of 0.2 hectares (0.4 acres). Updated distribution data would show a habitat decrease of approximately 0.17 hectares (0.32 acres) within the Tater Hill Plant Preserve.

Patch 3 was surveyed by the Plant Conservation Program on July 20th and was therefore not surveyed within the premise of this study. Conservation stewards are aware of *Lilium grayi* blooming within the Patch 3 area. Current area coverage for *Lilium grayi* Patch 3 is approximately 0.13 hectares (0.31 acres) within the Tater Hill Plant Preserve (Figure 8).

Patch 4 was surveyed and found to have one *Lilium grayi* flowering individual across 0.01 hectares (0.03 acres). Patch 4 is located on the left, near the first intersection of a walking path to Flat Woods Maintenance road off of Replogle Drive (Figure 8). Population viability concerns consist of multiple game trails moving through Patch 4 area; in addition to *Rubus spp.* (Blackberry vines) invading nearly all of the previous patch area of 0.02 hectares

(0.04 acres). Updated distribution data would show a habitat decrease of approximately 0.01 hectares (0.01 acres) within the Tater Hill Plant Preserve.

Patch 5 was surveyed and found to have no *Lilium grayi* flowering or vegetative individuals spread across approximately 0.02 hectares (0.04 acres). Patch 5 is located east of Miller Camp Maintenance road and at the base of Harmon Knob (Figure 7). Population viability concerns consist of drier habitat then that of most other *Lilium grayi* patches within the Tater Hill Plant Preserve. If Patch 5 is surveyed again and found to have no *Lilium grayi* it would represent a 0.02 hectare (0.04 acre) decrease in *Lilium grayi* area within the Tater Hill Plant Preserve.

Patch 6 was surveyed and found to have 27 *Lilium grayi* flowering individuals across 0.04 hectares (0.1 acres). Patch 6 is the furthest west population of *Lilium grayi* on Miller Camp Maintenance road (Figure 7). Population viability concerns consist of 8 individuals showing potential signs of blight, and 5 individuals showing herbivory damage by both *Odocoileus virginianus* (White-tailed deer), and members of the Formicidae family (ants) (Figure 9). Previous coordinate data listed Patch 6 as covering an area of 0.02 hectares (0.04 acres). Updated distribution data would show a habitat increase of *Lilium grayi* area of approximately 0.02 hectares (0.06 acre) within the Tater Hill Plant Preserve.

Patch 7 was not surveyed during the 2017 field season. It is currently located Northeast from the base of Harmon Knob. (Figure 8) The current coordinate data shows *Lilium grayi* area of approximately 0.02 hectares (0.04 acres) within the Tater Hill Plant Preserve.

Patch 8 was surveyed and found to have one *Lilium grayi* flowering individual across 0.01 hectares (0.02 acres). Patch 8 is located on the right of Flat Woods Maintenance road

before reaching the first stream crossing (Figure 8). Population viability concerns consist of suitable habitat being found, but only vegetative individuals persisting in the area. Previous coordinate data listed Patch 8 as covering an area of 0.02 hectares (0.04 acres), this would show a habitat decrease of *Lilium grayi* area of approximately 0.01 hectares (0.02 acres) within the Tater Hill Plant Preserve.

Patch 9 was surveyed and found to have no *Lilium grayi* flowering or vegetative individuals across 0.02 hectares (0.04 acres). Patch 9 is located in a seep like habitat, on the first walking path to the left on Flat Woods Maintenance road (Figure 8). Population viability concerns for Patch 9 was the complete lack of any plants. The habitat is ideal for the species so the lack of plants is disconcerting, since they were recorded in the past. If Patch 9 is surveyed again and found to have no *Lilium grayi* it would represent a 0.02 hectare (0.04 acre) decrease in *Lilium grayi* area on the Tater Hill Plant Preserve.

Patch 10 was surveyed and found to have no *Lilium grayi* flowering or vegetative individuals across 0.03 hectares (0.08 acres). Patch 10 is located just past the intersection of Miller Camp Maintenance road and Flatwoods Maintenance road on the right. (Figure 8) Conservation stewards are aware of *Lilium grayi* flowering individuals being present within this patch during the flowering time of early June. It is expected that surveys were conducted too late in flowering season for accurate counts within Patch 10. If Patch 10 is surveyed again and found to have no *Lilium grayi* it would represent a 0.03 hectare (0.08 acre) decrease in *Lilium grayi* area on the Tater Hill Plant Preserve.

Patch 11 was surveyed and found to have one *Lilium grayi* flowering and no vegetative individuals across 0.01 hectares (0.03 acres). Patch 11 is located near an area referred to as “The Chimneys”, but on the left side of Flat Woods Maintenance Road,

extending up slope within a seep habitat (Figure 8). Conservation stewards are aware of more extensive *Lilium grayi* flowering individuals being present within this area. It is expected that surveys were conducted too late in flowering season for accurate counts within Patch 11. If patch 11 is surveyed again and found to have no more *Lilium grayi* it would represent a 0.01 hectare (0.01 acre) decrease in *Lilium grayi* area on the Tater Hill Plant Preserve.

Patch 12 was surveyed and found to have no *Lilium grayi* flowering or vegetative individuals across 0.02 hectares (0.04 acres). Patch 12 is located 40.89 meters west of Patch 8 off of Flat Woods Maintenance Road (Figure 8) Conservation stewards are aware of *Lilium grayi* flowering individuals being present within this patch during the flowering time of early June. It is expected that surveys were conducted too late in flowering season for accurate counts within Patch 12. If Patch 12 is surveyed again and found to have no *Lilium grayi* it would represent a 0.02 hectare (0.04 acre) decrease in *Lilium grayi* area on the Tater Hill Plant Preserve.

Patch 13 was surveyed and found to have no *Lilium grayi* flowering or vegetative individuals across 2.77 hectares (6.85 acres). Patch 13 is located on the right side of Replogle drive near an area referred to as “The Horn of Tater” (Figure 8). Conservation stewards are aware of *Lilium grayi* flowering individuals being present within this patch during the flowering time of early June. It is expected that surveys were conducted too late in flowering season for accurate counts within Patch 13. In addition, Patch 13 is expected to be the second largest patch of *Lilium grayi* (in area) within the Tater Hill Plant Preserve. If Patch 13 is surveyed again and found to have no *Lilium grayi* it would represent a 2.77 hectare (6.85 acre) decrease in *Lilium grayi* area on the Tater Hill Plant Preserve.

Patch 14 was surveyed and found to have 11 *Lilium grayi* flowering individuals across 0.17 hectares (0.43 acres). Patch 14 is the first patch of *Lilium grayi* that Miller Camp Maintenance road runs directly through, just south of Harmon Knob. (Figure 7). Population viability concerns consist of more than 50 individuals in vegetative state showing signs of blight, and herbivory activity by both *Odocoileus virginianus* (White-tailed Deer), and members of the Formicidae family (ants) being in the area. Previous coordinate data listed Patch 14 as covering an area of 0.08 hectares (0.2 acres). Updated distribution data would show a habitat increase of *Lilium grayi* area of approximately 0.09 hectares (0.23 acre) within the Tater Hill Plant Preserve.

Patch 15 was surveyed and found to have no *Lilium grayi* flowering individuals across 0.02 hectares (0.06 acres) from the previous coordinate data provided, however, five individuals were found outside of the pre-2016 Patch 15 area. New patch shapefiles were created representing the Patch 15 population (Figure 7). Population viability concerns consist of more than 50 individuals in vegetative state showing signs of blight, and herbivory activity by both *Odocoileus virginianus* (White-tailed Deer), and members of the Formicidae family (ants) being in the area. Patch 15 is notably one of the largest populations of *Lilium grayi* (by number of individuals) within the Tater Hill Plant Preserve. Population viability is rated as poor since only a few individuals presented with flowers. Previous coordinate data listed Patch 15 as covering an area of 0.03 hectares (0.07 acres). Updated distribution data would show a habitat decrease of *Lilium grayi* area of approximately 0.02 hectares (0.06 acre) within the Tater Hill Plant Preserve.

Patch 16 was surveyed and found to have no *Lilium grayi* flowering or vegetative individuals. Patch 16 is currently located on either side of Rich Mountain road for

approximately 2.04 kilometers (1.26 miles) representing an area of approximately 2.53 hectares (6.26 acres; (Figure 10). Population viability is rated as poor based on concerns of unsuitable habitat for *Lilium grayi*. Habitat within Patch 16 is dry and resides partially on game lands and private property making the possibility of poaching probable. If Patch 16 is surveyed again and found to have no *Lilium grayi* it would represent a 2.53 hectare (6.26 acre) decrease in *Lilium grayi* area.

Patch 17 was surveyed and found to have 1158 *Lilium grayi* flowering individuals across 2.96 hectares (7.31 acres). Patch 17 is located within the largest grassy bald habitat of the Tater Hill Plant Preserve along with stretching down the walking path that connects to the Replogle Maintenance road (Figure 10). The PCP reports that Patch 17 is separately tracked element occurrence (146.034) within the Natural Heritage Programs database of rare species. Population viability concerns consist of game trails moving throughout Patch 17 and trespasser occurrence at which conservation stewards are aware. Previous coordinate data listed Patch 17 as covering an area of 2.35 hectares (5.79 acres) and residing east of new patch location. Updated distribution data would show a habitat increase of *Lilium grayi* area of approximately 0.61 hectares (1.52 acre) within the Tater Hill Plant Preserve.

Patch 18 was not surveyed during the 2017 field season. It is currently located south of the Tater Hill Plant Preserve on private property that is owned by Robert Carson Ragan (Figure 7). The current coordinate data shows *Lilium grayi* area of approximately 0.25 hectares (0.61 acres) within the Tater Hill Plant Preserve.

Patch 19 was surveyed and found to have 14 *Lilium grayi* flowering individuals across 0.11 hectares (0.27 acres). Patch 19 is located south of the Tater Hill Bog (Figure 7). Population viability concerns consist of *Rubus spp.* (Blackberry vines) invading peripheral

habitat. Previous coordinate data listed Patch 19 as covering an area of 0.19 hectares (0.48 acres). Updated distribution data would show a habitat decrease of *Lilium grayi* area of approximately 0.08 hectares (0.21 acre) within the Tater Hill Plant Preserve.

Patch 20 is a new patch added to the Tater Hill Plant Preserve. Patch 20 was found to have 30 *Lilium grayi* flowering individuals across 0.28 hectares (0.69 acres). Patch 20 is located west of the intersection of where Flat Woods road ends and Moonshine Creek walking trail begins (Figure 8). Population viability concerns consist of game trails throughout the area with notable amounts of herbivory occurring to *Lilium grayi* (Figure 11). There was no previous coordinate data listed on Patch 20. Updated distribution data would show a habitat increase of *Lilium grayi* area of approximately 0.28 hectares (0.69 acre) within the Tater Hill Plant Preserve.

Lilium grayi Conclusion

Surveys produced an approximate population of 1,250 flowering individuals spread out over a total of 3.61 hectares (8.92 acres). During the 2017 field season, 75% (15 of the *Lilium grayi* patches) in the Natural Heritage program EO 146.004 were surveyed on the Tater Hill Plant Preserve. In the patches that were surveyed, roughly 46% were surveyed past peak flowering time, possibly resulting in lower numbers; however, plant were observed with strong subpopulation in 45% of all current patches. Overall, the information collected during the 2017 *Lilium grayi* surveys provides insight into estimates of how long flowering times will last at the Tater Hill Plant Preserve (May 9th –May 27th), better information of possible bloom dates, knowledge of which patches to prioritize, and updated distribution data of *Lilium grayi* patches.

Future Threats

During the 2017 field season, individual *Lilium grayi* were noted as not flowering or showing potential effects of blight. Due to the potential risk, Cindy Bennet (East Tennessee State University) with previous experience studying *Pseudocercosporella inconspicua,* the fungus that causes Lily Leaf Spot Disease was invited to examine patches of *Lilium grayi.* Following similar protocols as East Tennessee State University, leaves were sampled and later examined by microscopy. Preliminary results indicated that Lily Leaf Spot Disease is present on the Tater Hill Plant Preserve (Figure 12).

Lilium philadelphicum

Lilium philadelphicum Linnaeus var. *philadelphicum,* Liliaceae is commonly known as the Wood Lily. This perennial herb is more frequently found in grassy balds, moist to wet meadows, and open woodland areas (Weakley 2015). It is also known as a facultative upland species usually occurring in non-wetlands, but it may also occur in wetlands (USDA 2015). It is easiest to identify when it blooms from June to July each year. *Lilium philadelphicum* is considered rare across its range and has a G5/T4-T5/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5/T4-T5 means the subspecies variety *Lilium philadelphicum* Var. *philadelphicum* populations are secure, or apparently secure, typically having considerably more than 100 occurrences around the globe and greater than 10,000 individuals. North Carolina ranks *Lilium philadelphicum Var. philadelphicum* as a S2, which refers to an imperiled population with typical occurrences ranging from 6 to 20 and between 1,000 and 3,000 individuals remaining in the state. During the 2017 field season, *Lilium philadelphicum* was identified on the Tater Hill Plant Preserve.

Surveys conducted produced an approximate population of 52 flowering individuals spread out over a total of 2.35 hectares (5.81 acres). Previous coordinate data had *Lilium philadelphicum* covering an area of 3.13 hectares (7.72 acres). Updated distribution data would show an area decrease of 0.78 hectares (1.91 acres) (Figure 13). The entire patch was located within the grassy bald habitat of camera area 4 of Tater Hill Plant Preserve. Using the Natural Heritage Rare Plant Survey Form, the population viability is rated as fair, with concerns of game trails moving throughout the *Lilium philadelphicum* patch and trespasser occurrence of which conservation stewards are aware.

Lonicera canadensis

Lonicera canadensis Bartram ex Marshall, Caprifoliaceae is commonly known as American Fly-honeysuckle. This perennial shrub is more frequently found in mountain bogs, high elevations, bouldery northern hardwood forests, hemlock and spruce swamps (Weakley 2015). It is also known as a facultative upland species usually occurring in non-wetlands, but may also occur in wetlands (USDA 2015). It is easiest to identify when it blooms from May to June each year. *Lonicera canadensis* is rare across its range and has a G4/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G4 means that *Lonicera canadensis* populations are apparently secure, typically having more than 100 occurrences around the globe or greater than 10,000 individuals. North Carolina ranks *Lonicera canadensis* as a S2, which refers to imperiled population with typical occurrences ranging from 6 to 21 and between 1,000 and 3,000 individuals remaining in the state. During the 2017 field season, *Lonicera canadensis* was not identified in any surveys on the Tater Hill Plant Preserve.

Meehania cordata

Meehania cordata (Nuttall) Britton, Lamiaceae is commonly known as Meehania. This perennial herb is more frequently found in moist, rocky, forested slopes with higher prevalence in rich boulderfield forests (Weakley 2015). It is known as a facultative upland species usually occurring in non-wetlands, but it may also occur in wetlands (USDA 2015). It is easiest to identify when it blooms from May to June each year. *Meehania cordata* is considered rare in parts of its mid-Atlantic distribution while being common in other parts of its distribution. It has a G5/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5 denotes a species as being common or widespread, typically having considerably more than 100 occurrences and more than 10,000 individuals remaining. North Carolina ranks *Meehania cordata* as a S2, which refers to an imperiled population with typical occurrences between 6 and 21 and number of individuals between 1,000 and 3,000 remaining in the state. During the 2017 field season, *Meehania cordata* was found within the Tater Hill Plant Preserve. Surveys conducted produced an approximate population of one flowering individual. A GPS waypoint will be used to represent locality rather than calculated area (Figure 14). No prior locality coordinate data existed for *Meehania cordata* on the Tater Hill Plant Preserve.

Mertensia virginica

Mertensia virginica (Linnaeus) Persoon ex Link, Boraginaceae is commonly known as Virginia Bluebells or Virginia Cowslip. This perennial herb is more frequently found in nutrient-rich, moist, alluvial soils of floodplain forests, and thickets (Weakley 2015). It is

known as a facultative wetland species, usually occurring in wetlands, but it may occur in non-wetlands (USDA 2015). It is easiest to identify when it blooms from March to May each year. *Mertensia virginica* is considered rare in parts of its mid-Atlantic distribution while being common in others. It has a G5/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5 denotes a species as being common or widespread, typically having considerably more than 100 occurrences and more than 10,000 individuals remaining. North Carolina ranks *Mertensia virginica* as a S2, which refers to an imperiled population with typical occurrences between 6 and 21 and number of individuals between 1,000 and 3,000 remaining in the state. During the 2017 field season, *Mertensia virginica* was found within the Tater Hill Plant Preserve (Figure 15). Surveys conducted produced an estimated population of more than 1,000 flowering individuals spread across approximately 0.69 hectares (1.70 acres). *Mertensia virginica* was divided into two separate patches with approximately 1.52 kilometers (0.94 miles) between patches. Patch 1 (southern patch) had approximately 4 individuals in a single clump. A single GPS waypoint will be used to represent locality rather than calculated area for Patch 1. Population viability concerns consist of nearby game trails, and the current location of Patch 1. The Patch 1 location is currently growing in the center of a walking path being illegally used for ATV trails. During the study, individuals were found dislodged from the original clump location, laying a few meters in the center of the path. Patch 2 (northern patch) had an estimated population of more than 1,000 flowering individuals spread across 0.69 hectares (1.70 acres). Using the Natural Heritage Rare Plant Form, population viability is rated as good with both vegetative and flowering individuals existing in Patch 2, with fruiting bodies being noted. Population viability concerns for Patch 2 consist of 76.81% of patch area residing on private

property. Current land management strategies such as timber extraction and mowing for hay occur on this private property, and could jeopardize future *Mertensia virginica* population growth. In addition, the invasive species *Rosa multiflora* (Multiflora Rose) was recorded as being within 100 yards of the *Mertensia* population. No prior coordinate data existed for *Mertensia virginica* and was thought to have been extirpated, not found in recent county surveys, or continued existence in Watauga County was uncertain (Robinson and Finnegan 2016). Discovery of *Mertensia virginica* adds one species to the overall conservation value of Tater Hill Plant Preserve.

Micranthes pensylvanica

Micranthes pensylvanica (Linnaeus) Haworth, Saxifragaceae is commonly known as Swamp Saxifrage. This perennial herb is frequently found in forested seeps, seepage swamps, and fens, usually over mafic or calcareous rocks (Weakley 2015). It is known as an obligate wetland species, usually only occurring in wetlands (USDA 2015). It is easiest to identify when it blooms from April to June each year, typically presenting with many white flowers. *Micranthes pensylvanica* is rare to uncommon across much of its range, but it currently has a G5/S1 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5 denotes a species as being common or widespread, typically having considerably more than 100 occurrences and more than 10,000 individuals remaining. North Carolina ranks *Micranthes pensylvanica* as a S1, which refers to critically imperiled population with typical occurrences being 5 or fewer and number of individuals being 1,000 or fewer remaining within the state. During the 2017 field season, *Micranthes pensylvanica* was identified within the Tater Hill Plant Preserve. Surveys conducted produced an

approximate population of 34 flowering individuals spread across approximately 0.18 hectares (0.47 acres). *Micranthes pensylvanica* was divided into three separate patches, with the largest distance between patches being 393.06 meters and the shortest distance between patches being 81.55 meters. (Figure 16) Patch 1 (southern patch) had an approximate area of 0.05 hectares (0.15 acres) and is recorded as being north of Tater Hill Bog by 197.72 meters (216.23 yards), and exists within pre-2016 Patch 2 locality. Previous coordinate data for Patch 1 listed *Micranthes pensylvanica* as covering an area of 3.12 hectares (7.70 acres). Updated distribution data for Patch 1 would show a decrease of *Micranthes pensylvanica* of approximately 3.07 hectares (7.55 acres). Patch 2 (central patch) had an approximate area of 0.11 hectares (0.27 acres) and is recorded as being north of the pre-2016 Patch 2 area by approximately 270.42 meters (295.74 yards) and approximately 15.15 meters south of the pre-2016 Patch 4 area. Previous coordinate data for Patch 2 listed *Micranthes pensylvanica* as covering an area of 0.21 hectares (0.53 acres). Updated distribution data would show a decrease of *Micranthes pensylvanica* by approximately 0.10 hectares (0.26 acres). Patch 3 (northern patch) had an approximate area of 0.02 hectares (0.05 acres) and is located within the pre-2016 Patch 4 area or 81.93 meters (89.60 yards) from current Patch 2. Previous coordinate data for Patch 3 listed *Micranthes pensylvanica* as covering an area of 3.12 hectares (7.70 acres). Updated distribution data for Patch 3 would show a decrease of *Micranthes pensylvanica* by approximately 3.12 hectares (7.65 acres). In surveying the pre-2016 Patch 4, no flowering individuals were identified. Updated distribution data would show a decrease of *Micranthes pensylvanica* by approximately 3.12 hectares (7.70 acres). Surveys for *Micranthes* were conducted in a single day, and recorded population numbers are for entire EO instead of individual patches. Geographic data was recorded in all areas where

Micranthes was identified. Updated distribution data for the *Micranthes* on Tater Hill Plant Preserve would represent a 9.39 hectare (23.20 acre) decrease in *Micranthes pensylvanica* area.

Packera crawfordii

Packera crawfordii (Britton) A.M. Mahoney & R.R. Kowal, Asteraceae is commonly known as Crawford's Ragwort. It is more frequently found in bog and fen habitats (Weakley 2015). Little is currently known about *Packera crawfordii,* and questions of its status as a species is currently under a debate (Mahoney and Kowal 2008). It is currently considered rare across its range and it has a G2-G3/S1 conservation status globally and in North Carolina. Globally, G2-G3 denotes inexact numeric rank referring to *Packera crawfordii* as typically having between 6 to 100 occurrences around the globe, or between 1,000 and 10,000 individuals. North Carolina ranks *Packera crawfordii* as a S1, which refers to a critically imperiled population with typical occurrences being 5 or fewer, and individuals as being below 1,000 within the state. During the 2017 field season, *Packera crawfordii* was not identified in any surveys on the Tater Hill Plant Preserve.

Packera schweinitziana

Packera schweinitziana (Nuttall) W.A. Weber & A. Love, Asteraceae is commonly known as New England Ragwort. It is more frequently found in grassy balds at high elevation generally over metagabbro or amphibolite (Weakley 2015). It is known as a facultative wetland species usually occurring in wetlands, but it may also occur in non-

wetlands (USDA 2015). *Packera schweinitziana* is rare across its range, and it has a G5-?/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5/? denotes an inexact numeric rank referring to *Packera schweinitziana* as typically having considerably more than 100 occurrences around the globe, or more than 10,000 individuals. North Carolina ranks *Packera schweinitziana* as a S2, which refers to imperiled population with typical occurrences ranging from 6 to 20 individuals and between 1,000 and 3,000 individuals remaining within the state. During the 2017 field season, *Packera schweinitziana* was not identified in any of our surveys on the Tater Hill Plant Preserve, but the conservation stewards are aware of at least one population (per. Comm. Estep). Previous coordinate data listed *Packera schweinitziana* as having an area of 1,253.39 hectares (3094.16 acres). If *Packera schweinitziana* is surveyed again and found to have no individuals it would represent a 1,253.39 hectares (3094.16 acres) decrease in *Packera schweinitziana* area within the Tater Hill Plant Preserve.

Platanthera flava var. herbiola

Platanthera flava (Linnaeus) Lindley *var. herbiola* (R.Brown) Luer, Orchidaceae is commonly known as Tubercled Rein Orchid. It is more frequently found in bogs and seepages (Weakley 2015). It is easiest to identify when it blooms from May to September each year. *Platanthera flava var. herbiola* is rare across the majority of its range, and it currently has a G4-?-T4-Q/S1? conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G4-?-T4-Q denotes an inexact numeric rank referring to the subspecies *Platanthera flava* var. *herbiola* also with questionable taxonomy that could resolve in lower-priority conservation status rank. *Platanthera flava var. herbiola* has an apparently secure

population with typically more than 100 occurrences around the globe and more than 10,000 individuals remaining. North Carolina ranks *Platanthera flava var. herbiola* as a S1, which refers to a critically imperiled population with typical occurrences of less than 5, and individuals remaining being less than 1,000 within the state. During the 2017 field season, *Platanthera flava var. herbiola* was not identified in any surveys on Tater Hill Plant Preserve.

Platanthera grandiflora

Platanthera grandiflora (Biglow) Lindley, Orchidaceae is commonly known as Large Purple Fringed Orchid or Plume-royal. It is more frequently found in bogs, seepages, and at moist places at high elevation (Weakley 2015). It is known as a facultative wetland species, usually occurring in wetlands, but it may occur in non-wetland areas as well (USDA 2015). It is easiest to identify when it blooms from June to early July each year. *Platanthera grandiflora* is rare across the majority of its range, and it currently has a G5/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5 denotes a species as being common or widespread, typically having considerably more than 100 occurrences and more than 10,000 individuals remaining. North Carolina ranks *Platanthera grandiflora* as a S2, which refers to an imperiled population with typical occurrences between 6 to 21 and number of individuals between 1,000 and 3,000 remaining in the state. During the 2017 field season, *Platanthera grandiflora* was identified on the Tater Hill Plant Preserve. Surveys conducted did not produce numbers of flowering individuals but did create area maps where *Platanthera* resides. *Platanthera grandiflora* was divided into three separate patches with the largest distance between patches being 2.81 kilometers (1.75 miles) and the shortest distance between patches being 881.12 meters (963.60 yards) (Figure 17). Patch 1 (southern patch) had an

approximate area of 0.26 hectares (0.63 acres). Previous coordinate data for Patch 1 listed *Platanthera grandiflora* as covering an area of 130.90 hectares (323.47 acres). Updated distribution data for Patch 1 would show a decrease of *Platanthera grandiflora* of approximately 130.64 hectares (322.84 acres). Patch 2 (central patch) had an approximate area of 0.44 hectares (1.08 acres). Previous coordinate data for Patch 2 listed *Platanthera grandiflora* as covering an area of 1,250.26 hectares (3,089.46 acres). Updated distribution data for Patch 2 would show a decrease of *Platanthera grandiflora* of approximately 1,249.82 hectares (3,088.38 acres). Patch 3 (northern patch) had an approximate area of 0.14 hectares (0.34 acres). There was no previous coordinate data for Patch 3. Updated distribution data for Patch 3 would show an increase of 0.14 hectares (0.34 acres). If *Platanthera grandiflora* is surveyed again and found to have no more individuals expanding its geographic range, it would represent a 1,380.32 hectares (3,411.96 acres) decrease in *Platanthera grandiflora* area within the Tater Hill Plant Preserve. Currently conservation stewards are aware of more populations, and these will be prioritized in future surveys (per. Comm. Estep).

Polemonium reptans var. reptans

Polemonium reptans var. reptans Linnaeus, Polemoniaceae is commonly known as Spreading Jacob's-ladder. This perennial herb typically grows in moist, nutrient-rich forests, such as bottomlands, and rich slopes (Weakley 2015). It is easiest to identify when it blooms from April to June each year. It ranges from common to rare across its range, and it has a G5-T5/S1 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5-T5 means the subspecies *Polemonium reptans* var. *reptans* or variety populations are secure, typically having considerably more than 100 occurrences around the globe, and

greater than 10,000 individuals. North Carolina ranks *Polemonium reptans* var. *reptans* as a S1, which refers to a critically imperiled population with typical occurrences of less than 5, and individuals remaining being less than 1,000 in the state. During the 2017 field season, *Polemonium reptans var. reptans* was not identified in any of surveys on the Tater Hill Plant Preserve.

Rhytidium rugosum

Rhytidium rugosum (Hedw.) Kindb. Rhytidiaceae is commonly known as Rhytidium Moss or Golden Tundra-moss. This nonvascular moss typically grows in high elevation rocky summits, grassy balds, glades, or over mafic rocks (Robinson and Finnegan 2016). It currently has a G5/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5 denotes a species as being common or widespread, typically having considerably more than 100 occurrences and more than 10,000 individuals remaining. North Carolina ranks *Rhytidium rugosum* as a S2, which refers to an imperiled population with typical occurrences between 6 to 21, and number of individuals between 1,000 and 3,000 remaining in the state. During the 2017 field season, *Rhytidium rugosum* was not identified in any of our surveys on the Tater Hill Plant Preserve.

Turritis glabra

Turritis glabra Linnaus, Brassicaceae is commonly known as Tower Mustard. This herb is often considered to be annual, biennial, and perennial (USDA 2015). *Turritis glabra* typically grows in open disturbed areas or on forest edges (Weakley 2015). It is easiest to identify when it blooms from May to June each year. It is uncommon in select areas of its

range, but it is rare through the majority of its range, and it currently has a G4-G5/S1 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G4-G5 denotes an inexact numeric rank referring to *Turritis glabra* as typically having considerably more than 100 occurrences around the globe, or more than 10,000 individuals. North Carolina ranks *Turritis glabra* as a S1, which refers to critically imperiled populations with typical occurrences being 5 or fewer, and individuals being below 1,000 within the state. During the 2017 field season, *Turritis glabra* was not identified in any surveys on the Tater Hill Plant Preserve.

Vaccinium macrocarpon

Vaccinium macrocarpon Aiton, Ericaceae is commonly known as Large Cranberry. This perennial shrub typically grows in mountain bogs, low pocosins with deep peat, and interdunal swales (Weakley 2015). This species is known as an obligate wetland species and almost always occurs in wetlands (USDA 2015). It is easiest to identify when it blooms from May to June each year. It is considered to be uncommon in its northern range but rare in its southern range, and it has a G5/S2 conservation status globally and in North Carolina (Robinson and Finnegan 2016). Globally, G5 denotes a species as being common or widespread, typically having considerably more than 100 occurrences and more than 10,000 individuals remaining. North Carolina ranks *Vaccinium macrocarpon* as a S2, which refers to imperiled populations with typical occurrences between 6 to 21, and number of individuals between 1,000 and 3,000 remaining in the state. During the 2017 field season, *Vaccinium macrocarpon*, was not identified in any of our surveys on the Tater Hill Plant Preserve, but the conservation stewards are aware of at least one population.

Conclusion

A total of 25 rare or endangered plant species are found on The Tater Hill Plant Preserve (per. Comm. Estep). During our 2017 field season, eight individual species were located and mapped. In addition, there remains prior coordinate data for three species that were not located during 2017 surveys. Currently, no coordinate data exists on the 14 remaining rare species within the boundaries of the Tater Hill Plant Preserve. During the 2017 field season, one species (*Mertensia virginica)* was discovered within the preserve, previously being a historical record within Watauga County with no locality data associated. Finally, coordinate data now exists for *Cardamine clematitis, Meehania cordata,* and individuals within the *Chelone* genus, of which more extensive surveys must be conducted for better determination of population size and health. Survey data from 2017 as compared to pre-2016 coordinate data represents a decrease of 1,397.04 hectares of rare plant habitat. This large number is somewhat misleading because the majority (98.8%) of this habitat loss is represented by *Platanthera grandiflora.* The species *Platanthera grandiflora* was previously represented by 1,381.16-hectare shapefiles signifying area coverage. Excluding the area loss of *Platanthera grandiflora,* there is still a loss of 16.72 hectares of previously designated rare plant habitat. Overall, the progression of maps and health of rare plant populations can be determined by future surveys. This study was designed to be a baseline from which future studies can evaluate the range expansion or reduction of rare plants within the preserve. In addition, abiotic features such as road placement, habitat designation, seeps, boulders, and trash locations were recorded to assist

in future surveys of new population or species locality. Rare plant populations should be monitored annually to ensure that the plant populations remain viable (Palmer 1987). Due to the limited resources available for the Tater Hill Plant Preserve, we recommend reporting every two to five years as a step towards annual monitoring. The only exception to this survey recommendation should be that of *Lilium grayi.* Our surveys indicate a total population decrease of 5.3 hectares. Signs of herbivory from both large vertebrates and small invertebrates were recorded within *Lilium grayi* patches. The identification of Lily Leaf Spot Disease and the high risk of trespasser poaching should be addressed immediately through better boundary markings and future surveys of *Lilium grayi*.

The results of our surveys provide better estimates of current rare plant distribution then previous coordinate data. The improved accuracy of this data allows for better quality land management decisions in the future. Overall, this study establishes a reference point from which the progression of conservation can occur in the Tater Hill Plant Preserve..

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Chapter 2 - Potential herbivory preference within a Southern Appalachian Mountain rare plant preserve

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Byron L. Burrell
Appalachian State University
Rankin Science Building, 572 Rivers Street
Boone, NC 28607
(336) 528-2941
burrellbl@appstate.edu

Potential herbivory preference within a Southern Appalachian Mountain rare plant preserve.

BYRON L. BURRELL, Appalachian State University, Rankin Science Building, 572 Rivers Street, Boone, NC 28608, USA

ZACH J. FARRIS, Appalachian State University, Holmes Convocation Center, 111 Rivers Street, Boone, NC 28608, USA

MATT C. ESTEP [1] Appalachian State University, Rankin Science Building, 572 Rivers Street, Boone, NC 28608, USA[1]

ABSTRACT *Odocoileus virginianus*, also known as White-tailed Deer, is a widespread species that has shown the ability to alter habitats and have a negative effect on forest regeneration. Though the effects of *O. virginianus* have been studied, literature on predation of rare plants is still limited by comparison. In an effort to support rare plant conservation, *O. virginianus* patterns within a rural southern Appalachian Mountain plant preserve were examined to conclude characteristics that influence behavior. This study provides data that can assist management strategies such as placement of exclosures, locations to conduct lethal

[1] Author for correspondence (email: estepmc@appstate.edu)

management, translocation, and hunting for the purpose of conservation of rare species within the Tater Hill Plant Preserve. This study employed trail camera technology to look at occupancy and detection of *O. virginianus* over the course of a year within the Tater Hill Plant Preserve. Biotic and abiotic covariates explaining detection of *O. virginianus* varied by season. Detection models were best explained by boundaries of the plant preserve along with man-made paths, and co-occurring species such as *Meleagris gallopavo* (North American Turkey), *Lynx rufus* (Bobcat), and *Canis latrans* (Coyote). Occupancy models were best explained by distance to the plant species *Cardamine clematitis*. This information provides land managers with an understanding of *Odocoileus virginianus* habitat selection, temporal patterns, and spatial distribution.

KEY WORDS: Appalachian Mountain; camera-trapping; detection; habitat selection; management; nature preserve; occupancy; white-tailed deer; rare species; trail camera

White-tailed deer (*Odocoileus virginianus)* populations have increased across the United States since the late 20th century (Blackard 1971). Due to rising populations, problems such as deer-vehicle collisions, damage to agricultural crops, and reduction of plant diversity have also increased (Vercauteren and Hygnstrom 1993, Healy 1997, DeNicola and Williams 2008). Similar to these problems, there has been a focus on how white-tailed deer interact with their environment and affect the landscape. Several studies have shown the direct effects of white-tailed deer to reduce plant growth and increase plant mortality (Prachar and Samuel 1988, Anderson 1994, Rooney et al. 2000). Other studies have examined the indirect effects that white-tailed deer can have in facilitating invasive species (Knight et al. 2009). Finally,

Rooney and Waller (2003) determined that white-tailed deer can affect forest regeneration and should be considered a keystone herbivore (Rooney and Waller 2003). These studies highlight the impact that white-tailed deer can have on the environment.

As research has focused on understanding the effects deer have on plants, many methods have developed to investigate and explain these interactions. Research methodology has included the use of exclosures to examine effects of white-tailed deer on plant populations, clipping experiments to simulate levels of deer browsing, and radio collaring to examine home range size and dispersal (Canham et al. 1994, Bowers 1997, Henderson et al. 2017). While many of these methods have been used for more than six decades, recent technological advancements have allowed for an expansion of work on camera trapping and population modeling (Russell et al. 2001, Rovero et al. 2013). Camera traps provide a cost effective, non-invasive approach to investigate vertebrate-habitat relationships (Rovero et al. 2013). Nichols et al. (2011) described camera trapping as representing two possible options: (1) to gain an understanding of how ecosystem components work in unison (representing science) or (2) collecting data for the purpose decision making to improve or modify an ecosystem for future use (representing management). This study utilizes trail cameras for both science and management, and we suggest that management decisions cannot be made without first understanding how ecosystem components work synergistically.

Regardless of the technique used to decrease white-tailed deer density, first we need to accurately describe where white-tailed deer are and the plants or habitats with which they interact. The goal of our study is to investigate the spatial distributions and habitat use across seasons, including the influences of biotic and abiotic factors, on white-tailed deer populations within the Tater Hill Plant Preserve. For each season, we carried out the

following objectives: a) estimate occupancy and detection of deer within the preserve; b) investigate the relationship between probability of site occupancy by white-tailed deer and biotic variables (rare plant species, co-occurring species, habitat types); and c) investigate the relationship between probability of site occupancy by white-tailed deer and abiotic variables (maintenance roads, walking paths, and preserve boundaries). The results of this study will allow for a better understanding of white-tailed deer spatial and temporal activity patterns and aid the development of targeted, effective management recommendations for the Tater Hill Plant Preserve.

STUDY AREA

The Tater Hill Plant Preserve is a 486-hectare preserve located in northwest Watauga County, NC and has been owned operated by the North Carolina Department of Agriculture's Plant Conservation Program since August of 2000. The preserve currently protects more than 20 rare and state listed species of plants over a multitude of habitats. The Tater Hill Plant Preserve habitats range from high elevation rock outcrops, rich cove forests, northern hardwood forests, to a mountain bog ecosystem. Elevation within The Tater Hill Plant Preserve ranges between 1,082 meters to 1,644 meters and preserve boundaries stretch for approximately 5.6 km at its longest and 1.52 km at its widest. The preserve has a few designated maintenance roads with several old logging paths used for walking trails by management.

METHODS

To evaluate seasonal spatial occupancy patterns for white-tailed deer within the Tater Hill Preserve and their relationship with biotic and abiotic variables, we conducted habitat and trail camera surveys from January 21st 2017 to January 22nd 2018. For both habitat and

camera surveys we used a stratified random sampling technique paired with a systematic layout to provide a random analysis of the entire preserve. The Tater Hill Plant Preserve was divided into 12 equal area sections (hereafter referred to as Camera Areas) following Quality Deer Management Association protocol recommendations for survey design (Thomas Jr 2010). These camera areas were divided east to west to follow elevation gradients known to coincide with relative plant habitats. A 200 m by 200 m grid for camera placement was created using the add-in tool ETW Geowizard 11.3 (ET SpatialTechniques, Faerie Glen, ZA) for ArcMap 10.3.1 (Esri, Redlands, CA, USA) (NCMNS 2016). Once grids were created, we developed grid centroids using the calculate geometry and display XY function of Arcmap. Centroids were given a random number using the Excel add-in tool Kutool (Addin Technology, Inc., Hainan, CN). Kutool was then used to create a list of random numbers determining the location of cameras traps (Hereafter referred to as Camera Site) within Camera Areas per month. Camera placement was standardized following the methods of Cusack et al. (2015) by placing all cameras within a 50 m buffer of grid centroids (Cusack et al. 2015). The use of this buffer combined with a grid size of 200 m by 200 m ensured minimum distance between sample locations would remain 100 m. The mixture of grid reliance and a 50 m field buffer allows for a random and non-random camera placement, permitting for accurate measures of occupancy and detection rates to occur throughout the preserve.

Our camera sites consisted of one, motion-activated camera with light-emitting diode (LED) flash. We employed 12 cameras traps of the same model to decrease variability in detection rates based on different motion sensor technology. We mounted Cuddeback Long Range IR (Cuddeback Digital, WI, USA) at the lowest height above vegetation level to allow

detection of vertebrates without compromising photographic rates of larger species (Kelly 2008). Individual camera sites were located in the field using a Garmin 64st (Garmin International, Inc., Olathe, Kansas, USA) and oriented to offer a reasonably uncluttered view of a game trail or natural wildlife attractant (downed log, potential denning site, or facing vegetation with high likelihood of predation). If neither a game trail nor a natural wildlife attractant could be found within the 50 m buffer from grid centriod, the camera was placed looking into an open area with prioritization to face north following Quality Deer Management Association recommendations (Thomas Jr 2010). We attempted to place camera traps at each Camera Site for 28 to 31 days before moving to new Camera Site within each Camera Area. The operation of 12 different cameras, one in each Camera Area, moved every month, over the course of a year, allowed for a total of 144 sample sites across the preserve. We defined an independent capture event as all photos of a vertebrate species within less than three minutes of separation between photos. Independent capture event time interval was chosen as it fell within a range of times used by previously published studies (Kays et al. 2010, Meek et al. 2014, Kays et al. 2015). This research was approved by Appalachian State University Institutional Animal Care and Use Committee (protocol number 17-08).

Rare plant distributions were located and mapped using modified wandering surveys (Kell 2006). These wandering surveys typically relied on the path of least resistance between trail cameras. Some locality data were provided by the North Carolina Department of Agricultures and Consumer Services Plant Conservation Program (hereafter referred to as PCP). Rare plant distribution were created from waypoints taken near peripheral rare plants within a distribution. Waypoints were used as vertex locations in conjunction to the Create

Feature Class tool of ArcMap 10.3.1 Data Management Toolbox. All Rare Plants 2016 was defined as all rare plant distribution data provided by the PCP. All Rare Plants 2017 was defined as all rare plant distribution data that was updated from 2017 wandering surveys. Values for nearest distance of biotic (rare plants) covariates to centroid location was calculated using the Near tool from Analysis toolbox within ArcMap 10.3.1.

Habitats at each Camera Site were determined using a point plot sampling technique, currently used for determination of species richness by the U.S. Forestry Service (Wrobley and Sullivan 1985). Once species richness profiles were created for each Camera Site, habitats were defined using MP Schafale's fourth approximation (Schafale 2012).

To assess abiotic relationship, we related probability of occurrence to camera distance from anthropogenic features occurring within, and around the Tater Hill Plant Preserve such as: maintenance roads, walking paths, maintenance roads combined with walking paths, and preserve boundaries derived using ArcMap 10.3.1. For the purpose of this study, we defined maintenance roads as roadways in which non 4x4 vehicles could access under normal conditions. Walking paths were defined as flat paths that may have previously been utilized for timber extraction or a path in which an ATV could travel if necessary. Preserve boundaries were derived using ArcMap 10.3.1 in conjunction with Watauga County NC parcel tax information. Values for nearest distance of abiotic covariates to centroid location was calculated using the Near tool from Analysis toolbox within ArcMap 10.3.1.

To assess (biotic) rare plant relationships, we related probability of occurrence to camera distance from rare plant distribution occurring within, and around the Tater Hill Plant Preserve such as: *Cardamine clematitis*, *Delphinium exaltatum*, *Geum geniculatum*, *Lilium*

grayi, *Lilium philadelphicum*, *Mertensia virginica*, *Micranthes pensylvanica*, *Platanthera grandiflora*, all rare plant distribution 2016, and all rare plant distribution 2017 (Table 2).

To assess (biotic) co-occurring species relationships, we calculated and used as covariates the relative activity (e.g. camera trap success) of co-occurring vertebrates within the Tater Hill Plant Preserve, including: coyote (*Canis latrans*), domestic dog (*Canis familiaris*), American black bear (*Ursus americanus*), bobcat (*Lynx rufus*), wild turkey (*Meleagris gallopavo*), and human (*Homo sapiens*; classified as "Trespasser"). Trap success was defined as number of independent capture events divided by the survey effort (total number of days camera trap was at a Camera Site).

To model probability of detection (*p*), and probability of site occupancy (Ψ) within individual seasons, we defined seasons as: Fall (Sept 22nd-Dec 20th), Winter (Dec 21st – Mar 19th), Spring (Mar 20th – June 20th), Summer (June 21st – Sept 21st). To model occupancy (Ψ), we created a capture history for white-tailed deer by recording if there were one or more detections (1) or no detections (0) for each trap night. We defined a trap night as a 24-h in which at least one camera trap at a Camera Site was properly functioning. To improve model convergence we collapsed trap nights sampling period to 15-day sampling periods. Before modeling, we created a priori models to avoid possible bias. We estimated white-tailed deer simple single-season occupancy for each of the four seasons using Presence software 2.12.10 (USGS, MD, USA). We used Akaike information criterion (AIC) for model selection and reported all top-ranking models (ΔAICc < 2.0) for each season. We first estimated detection probability (*p*) (holding Ψ constant) to define which biotic or abiotic covariates best explained detection. Once covariates best explaining detection were identified, *post hoc* a priori models were created further evaluating covariate relationship to probability of white-

tailed deer detection. Once the covariate or covariate combination that best explained *p* models was determined, we examined the relationship between Ψ and the 21 abiotic and biotic covariates listed above. Finally, to assess model fit and ensure there was no over-dispersion (c-hat < 3.0) we conducted a Goodness of fit test (p>0.05) using 1,000 bootstraps.

RESULTS

Our entire survey period resulted in 4,295 trap nights (mean = 358 ± SD = 7.93 per camera area, mean = 29.83 ± SD = 5.55 per camera site) and provided a total of 31,041 photos of all vertebrates. White-tailed deer accounted for approximately 84.02% (26,080) of total vertebrate pictures while co-occurring species of interest such as Coyote, Dog, Bear, Bobcat, Turkey and Trespasser contributed 326 (1.05%), 60 (0.19%), 730 (2.35%), 100 (0.32%), 440 (1.42%) and 935 (3.01%) respectively (Figure 18). In total, 23 vertebrate species were identified within the Tater Hill Plant Preserve during the entire survey period (Table 3). When comparing white-tailed deer occupancy across seasons we found the probability of site occupancy (Ψ) varied across seasons, but error bars overlapped indicating non-significance. Probability of site occupancy was highest during the spring (Ψ = 0.97, SE = ±0.03) and lowest during winter (Ψ = 0.91, SE = ±0.05); Figure 19). When comparing white-tailed deer detection across seasons we found the probability of detection (*p*) differed between seasons, with probability of detection being highest during the summer (*p* = 0.49, SE = ±0.03) and lowest during winter (Ψ = 0.35, SE = ±0.04); Figure 20).

Winter

We had a total of 31 Camera Sites over the winter resulting in a mean survey period length of 32.2 days (± 1.25 [SE]). There were 14 models with ΔAIC value < 2.00, with our top model indicating probability of site occupancy best explained by constant, while

probability of detection was best explained by the nearest distance to either a walking path or a maintenance road and the trap success of the co-occurring species coyotes (β = 2.29, SE = ±0.64; Table 4). In evaluation of winter (*p*) covariates individually, the nearest distance to either a walking path or a maintenance road were shown to have a negative influence on white-tailed deer detection (β = -0.003, SE = ±0.001; Figure 21), and trap success of coyote was shown to have a positive influence on white-tailed deer detection (β = 0.06 SE = ±0.03; Figure 21).

Spring

We had a total of 36 Camera Sites over the Spring resulting in a mean survey period length of 28.86 days (± 0.65 [SE]). There were 2 models with ΔAIC value < 2.00, with our top model indicating probability of site occupancy is best explained by preserve boundaries, whereas probability of detection was best explained by the nearest distance to a maintenance road and trap success of the co-occurring species wild turkey (β = 15.10, SE = ±3.07; Table 4). In evaluation of the spring (Ψ) covariate preserve boundaries, it was shown to have a negative influence on probability of site occupancy for white-tailed deer (β = -0.09 SE = ±0.02). In evaluation of spring (*p*) covariates individually, the nearest distance to a maintenance road was shown to have a negative influence on white-tailed detection (β = -0.001 SE = ±0.0002; Figure 21), whereas trap success of co-occurring species wild turkey had a positive influence on white-tailed deer detection (β = 0.07 SE = ±0.03; Figure 21).

Summer

We had a total of 48 Camera Sites over the Summer resulting in a mean survey period length of 31.56 days (± 0.77 [SE]). There were 6 models with ΔAIC value < 2.00, with our top model indicating probability of site occupancy best explained by *Cardamine clematitis*,

whereas probability of detection was best explained by nearest distance to a maintenance road and trap success of co-occurring species wild turkey (β = -2.92 SE = ±1.10; Table 4). In evaluation of summer (Ψ) covariate *C. clematiatis*, it was shown to have a positive influence on probability of site occupancy for white-tailed deer (β = 0.005 SE = ±0.0006). In evaluation of summer (*p*) covariates individually, the nearest distance to a maintenance road was shown to have a negative influence on white-tailed deer detection (β = -0.002 SE = ±0.0004; Figure 22), whereas trap success of co-occurring species wild turkey had a negative influence on white-tailed deer detection (β = -0.13 SE = ±0.05; Figure 22

Fall

We had a total of 29 Camera Sites over the Fall resulting in a mean survey period length of 32.58 days (± 1.01 [SE]). There were 2 models with ΔAIC value < 2.00, with our top model indicating probability of site occupancy best explained by constant, while probability of detection was best determined by distance to preserve boundary and trap success of co-occurring species bobcat (β = 2.60 SE = ±0.73; Table 4). In evaluation of summer (*p*) covariates individually, the nearest distance to preserve boundaries was shown to have a positive influence on white-tailed deer detection (β = 0.02 SE = ±0.003; Figure 22), whereas trap success of co-occurring species bobcat had a positive influence on white-tailed deer detection (β = 0.34 SE = ±0.11; Figure 22).

DISCUSSION

Our findings indicate white-tailed deer represent 82.05% of the vertebrate species composition on the Tater Hill Plant Preserve (Figure 18). Temporal estimates from our study indicate that white-tailed deer detection increased during the summer and fall from that of spring and winter (Figure 20). Our data of white-tailed deer seasonal patterns is similar to

results found by Massé and Côté (2013) which also indicated increases in movement patterns by white-tailed deer from winter to summer (Massé and Côté 2013). Increases of activity throughout the summer could be due to females begin to birthing fawns in late spring (Chitwood et al. 2015). This potential increase in population may be contributing to higher detection rates. Additionally, during the summer, white-tailed deer are maximizing foraging potential as they prepare for the upcoming breeding season. The evidence of increased activity during the summer season transiently corresponds to mating behavior of white-tailed deer within the Southeastern United States, and parallels other studies showing that white-tailed may increase, or even change their home range during the breeding season (Sullivan et al. 2017, Soto-Werschitz et al. 2018).

Biotic Variables

In determining biotic variables that contribute to the probability of site occupancy and probability of detection, we found results varying by season. During the winter, though not in our top model, we found that probability of site occupancy was negativly influenced by distance to *Cardamine clematitis* (Figure 23). Data shows that as distance from *Cardamine clematitis* increases, the probability of site occupancy begins to decrease. This habitat selection by white-tailed deer contradicts other studies in regards to preferences lower elevation, lower slope gradients, and lower snow accumulation typically selected for by white-tailed deer during the winter (Schoen and Kirchhoff 1985, Ganskopp and Vavra 1987, Lesage et al. 2000). The non-typical behavior leads us to believe that the association demonstrated is more strongly related to habitat characteristics or possibly co-occurring lichen species prevalent in the same habitat *C. clematiatis* resides in. Additionally, *C. clematitis* is dormant during the winter further providing evidence for its lack of contribution

for white-tailed deer behavior. The only population of *C. clematitis* in the Tater Hill Plant Preserve is located on a steep slope (34 to 64%) and near the highest elevations within the preserve. Lichens heavily cover the area shared by *C. clematitis*, which may serve as an adequate food source during the winter. Past studies have shown that white-tailed deer utilize lichens for browsing in times when food sources are low (Gray and Servello 1995, Tremblay et al. 2005).

During the summer, we found that distance to *Cardamine clematitis* positively influenced probability of occupancy for white-tailed deer (Figure 23). We hypothesize once again that it is not *C. clematiatis* but rather the habitat it resides in. Previous studies have shown that deer reduce activity in areas with slopes in excess of 40% (Ganskopp and Vavra 1987). White-tailed deer have also been shown to conserve energy by choosing lower slope gradients (Moen 1976). The use of more level areas combined with the idea that deer only use lichens as a food source when browse is low may indicate that deer are exploiting lower slopes and food that is more accessible to better control energy expenditures.

Abiotic Variables

During our investigation, we found that either constant values or distance to preserve boundaries were our highest ranking occupancy covariate. If we looked past constant values, it can be determined that distance to preserve boundaries was the highest ranking occupancy covariate that still met our minimum requirement of < 2.00 ΔAIC value. During the winter, probability of site occupancy for white-tailed deer had a positive influence with distance to preserve boundaries. We hypothesize that deer are using the internal areas of the preserve as a refuge to avoid the neighboring Elk Knob State Game Land or hunting that occurs on private property. Previous studies suggest that deer will select for areas where perceived

hunting pressure is low and select for dense cover during hunting season (Swenson 1982, Kilgo et al. 1998).

During all other seasons (spring, summer and fall), probability of occupancy by white-tailed deer was negatively related to distance from preserve boundaries. We hypothesize this negative relationship might be due to edge habitat, and agriculture selection preferences by white-tailed deer to that of neighboring parcels. Studies show fields with ≥ 50 m to forested edge increase potential of deer browse due to closeness of cover (Lyon and Scanlon 1987). Furthermore, white-tailed deer may be using edge habitat corridors created by roadways.

MANAGEMENT IMPLICATIONS

Our research indicates spatial and temporal patterns of white-tailed deer within the Tater Hill Plant Preserve. Our study suggests that biotic variables such as *Cardamine clematitis* or habitat characteristics where it is found, influence white-tailed deer probability of site occupancy and that abiotic variables such as preserve boundaries. While our data suggest seasonal changes in site occupancy by white-tailed deer to *Cardamine clematitis,* we speculate geographic features and co-occurring species are more accurately responsible. In an effort to fully understand the relationship between white-tailed deer site occupancy and the *Cardamine clematitis* habitat distribution, we recommend management conduct future studies in this area of the preserve. In regards to the abiotic variables of this study, this information could benefit conservation stewards and land managers in white-tailed deer management on the Tater Hill Plant Preserve. Our data suggests that due to the frequency of which trespassers occur and the current probability of site occupancy by white-tailed deer, that boundary marking may be essential. Furthermore, if the implementation of exclosures

used to protect rare and endangered species is used, then our data suggest the prioritization of rare plants near preserve boundaries during flowering times of the year (spring, summer and fall). If management considers other wildlife management strategies such as translocation, lethal management or hunting, then our data indicates areas highest occupancy from which trap locations could be determined across different seasons.

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Figure Captions

Figure 18. Vertebrate species composition within the Tater Hill Plant Preserve 2017

Figure 19. Probability of site occupancy (Ψ) of white-tailed deer within the Tater Hill Plant Preserve in 2017 by season

Figure 20. Probability of detection (*p*) of white-tailed deer within the Tater Hill Plant Preserve in 2017 by season

Figure 21. Covariate influence on detection (*p*) of white-tailed deer within the Tater Hill Plant Preserve in 2017 as represented by winter and spring.

Figure 22. Covariate influence on detection (*p*) of white-tailed deer within the Tater Hill Plant Preserve in 2017 as represented by summer and fall.

Figure 23. Biotic covariate *Cardamine clematitis* influence on probability of white-tailed deer occupancy within the Tater Hill Plant Preserve during 2017 surveys

Figures

Figure 18. Vertebrate species composition within the Tater Hill Plant Preserve 2017

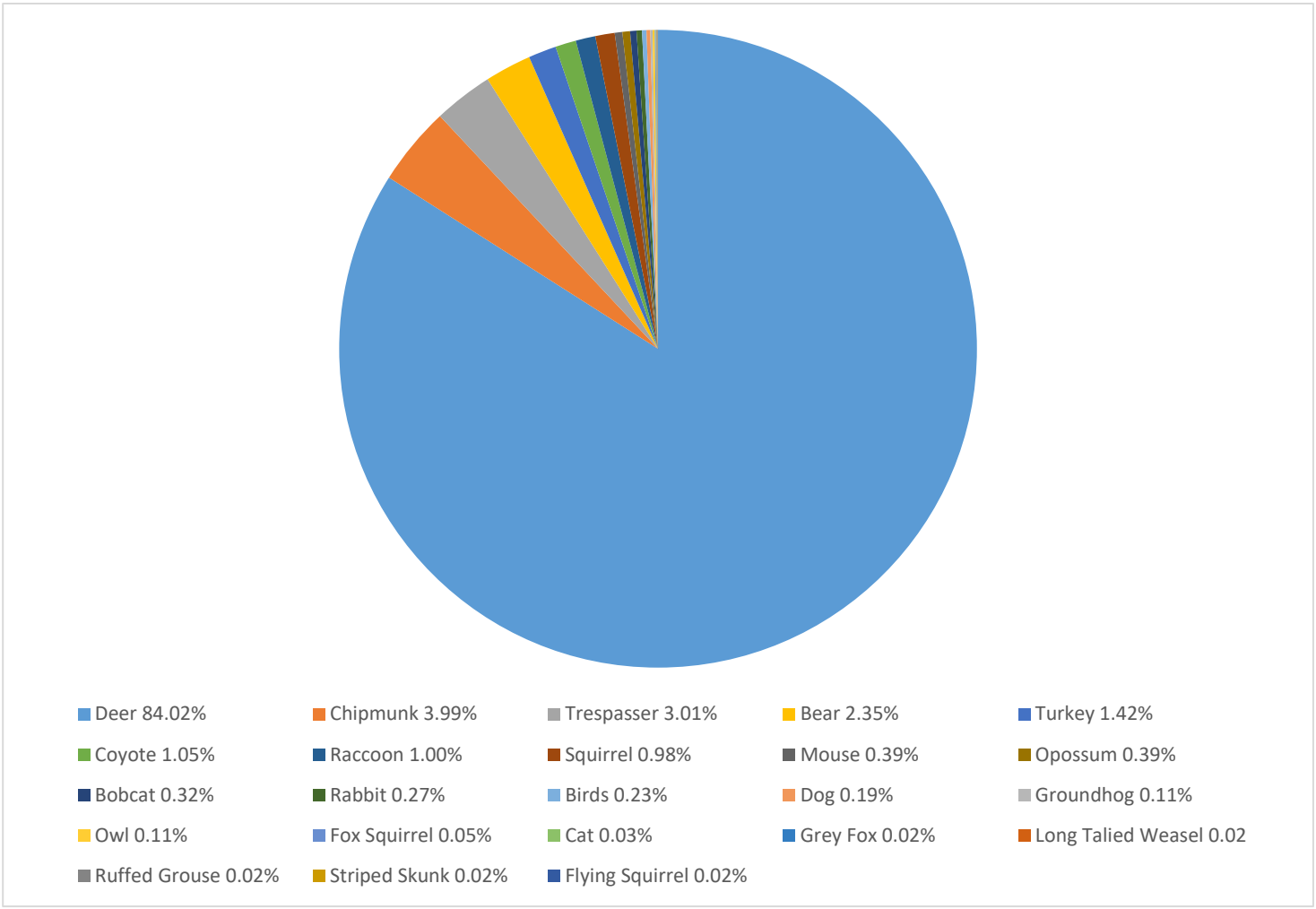


Figure 19. Probability of site occupancy (Ψ) of white-tailed deer within the Tater Hill Plant Preserve in 2017 by season

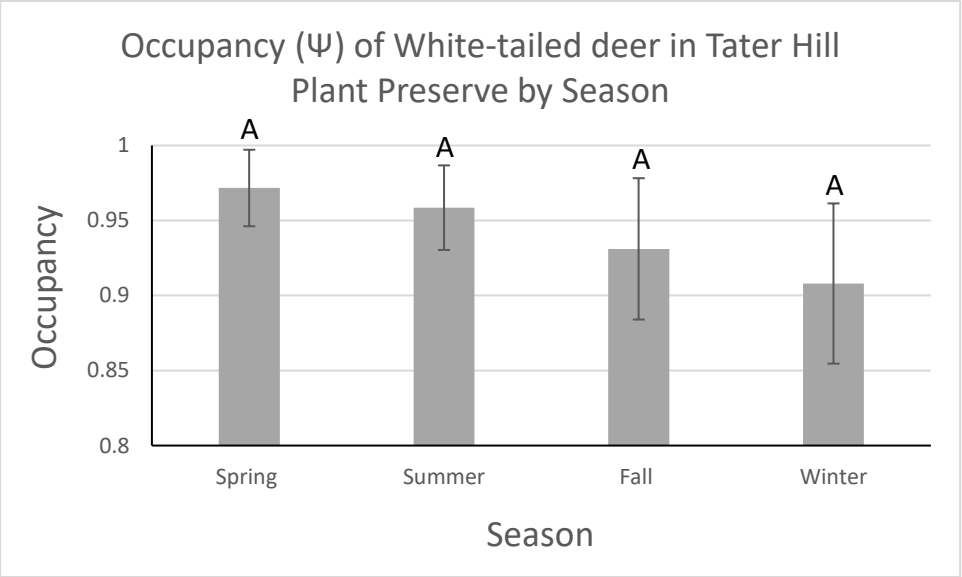


Figure 20. Probability of detection (*p*) of white-tailed deer within the Tater Hill Plant Preserve in 2017 by season

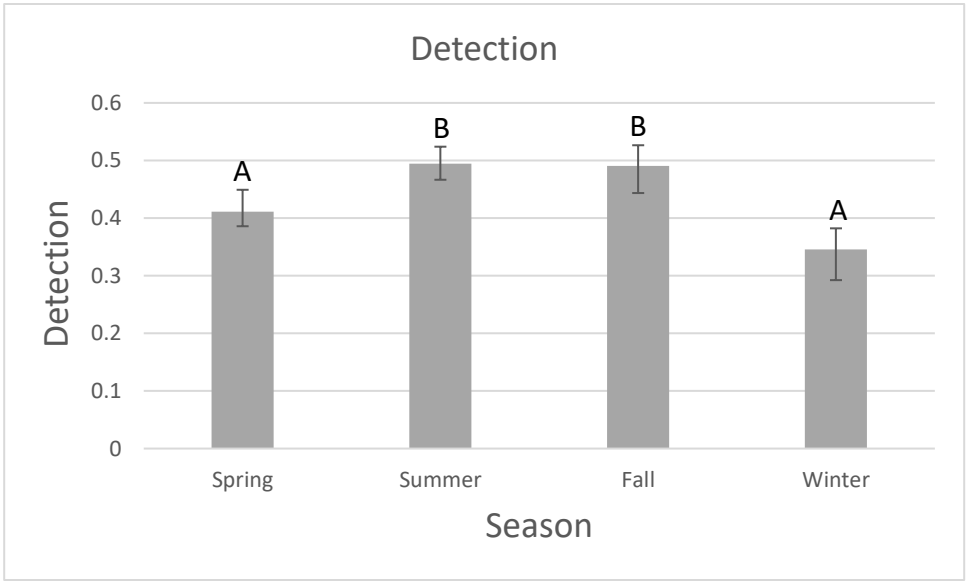


Figure 21. Covariate influence on detection (*p*) of white-tailed deer within the Tater Hill Plant Preserve in 2017 as represented by winter and spring.

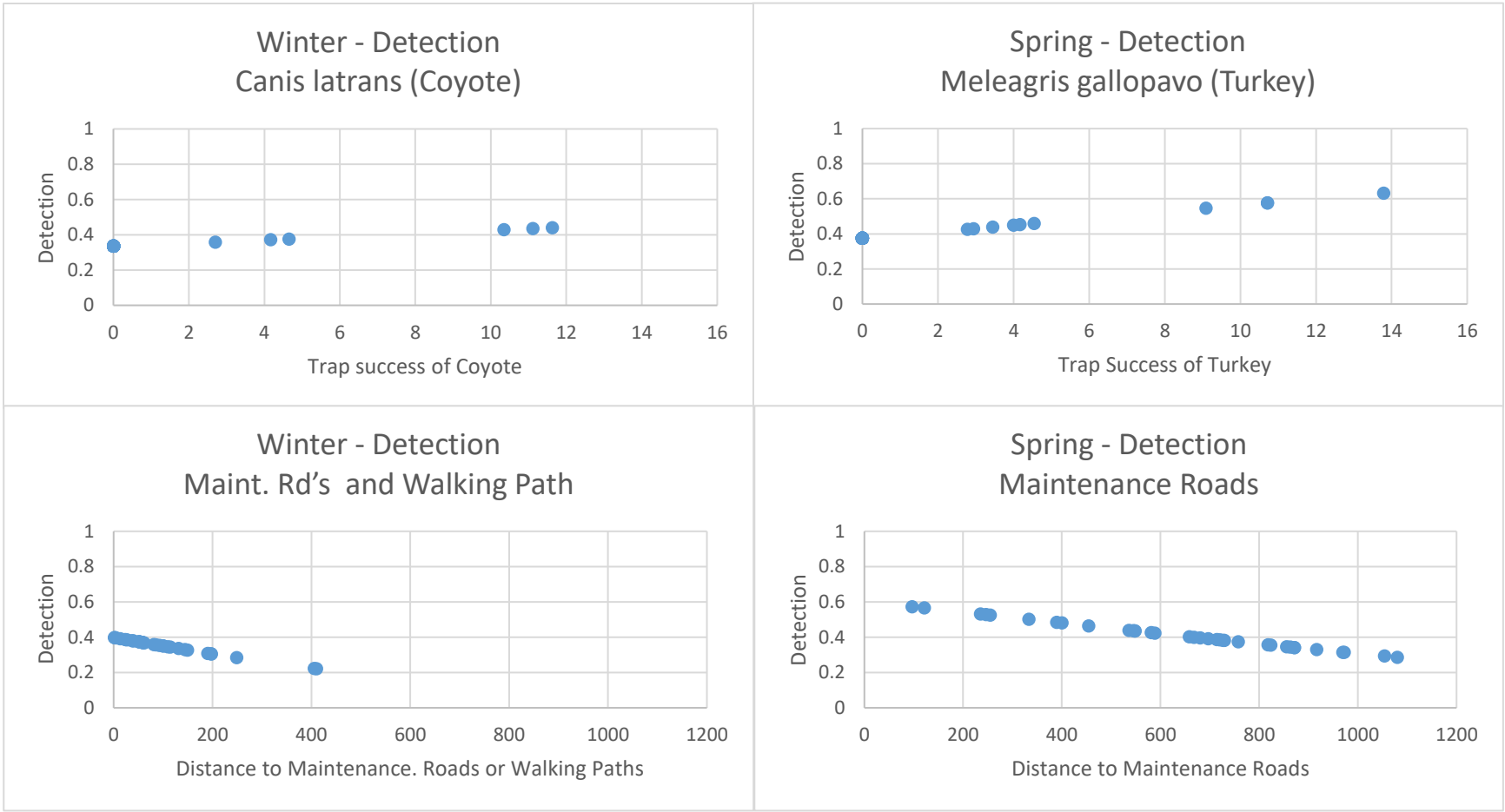


Figure 22. Covariate influence on detection (*p*) of white-tailed deer within the Tater Hill Plant Preserve in 2017 as represented by summer and fall.

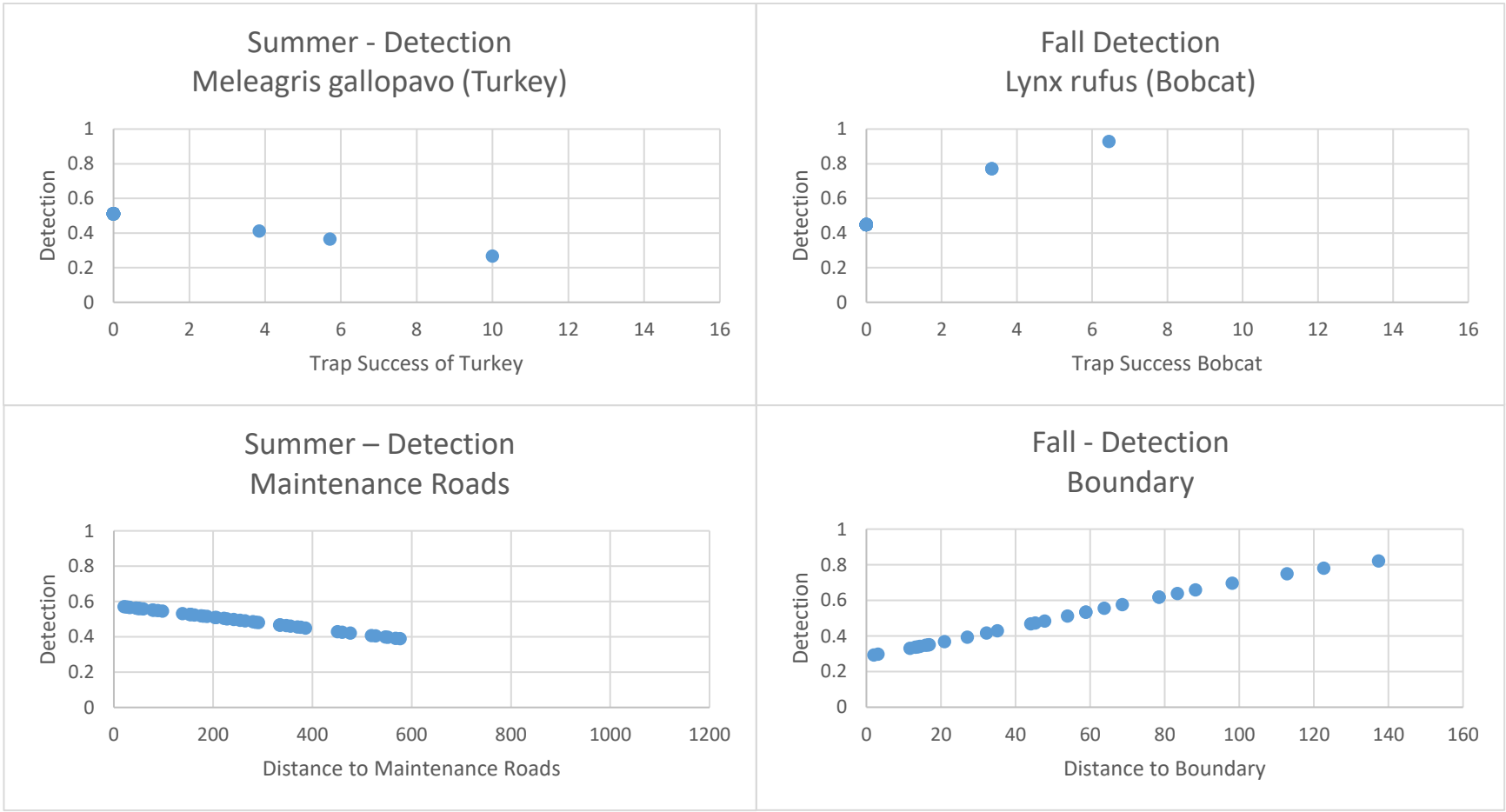
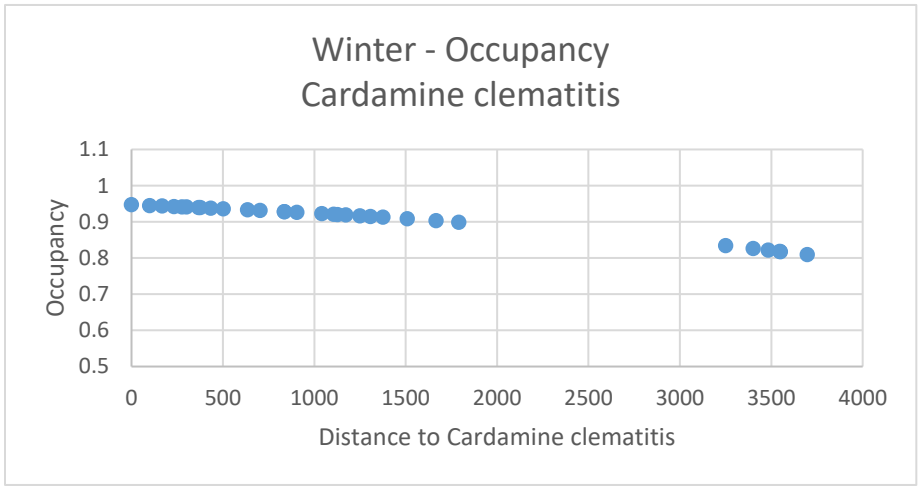
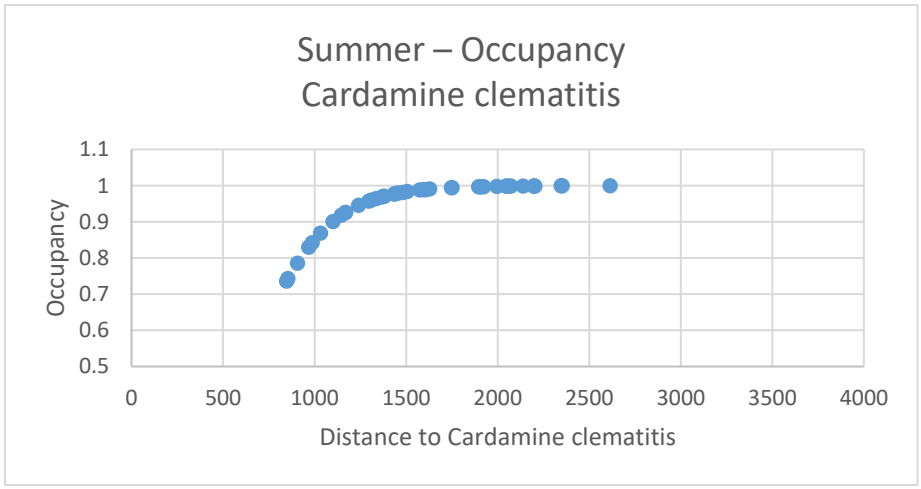


Figure 23. Biotic covariate *Cardamine clematitis* influence on probability of white-tailed deer occupancy within the Tater Hill Plant Preserve during 2017 surveys





Tables

Table 2. State listed plant species utilized for herbivore relationships analysis within the Tater Hill Plant Preserve, North Carolina, USA, January 2017 – January 2018

Plant Species	Current Conservation Status per North Carolina Natural Heritage Program
Cardamine clematitis	Rare
Delphinium exaltatum	State Listed
Geum geniculatum	State Listed
Lilium grayi	State Listed
Lilium philadelphicum	State Listed
Mertensia virginica	State Listed
Micranthes Pensylvanica	State Listed
Platanthera grandiflora	State Listed

Table 3. Number of photos by species and camera area for the Tater Hill Plant Preserve, North Carolina, USA, January 2017 – January 2018

Species Name	Camera Area												
	1	2	3	4	5	6	7	8	9	10	11	12	Totals
Bear	20	150	30	250	25	65	35	30	15	25	60	25	730
Birds	0	0	5	5	0	5	50	5	0	0	0	0	70
Bobcat	0	0	10	10	15	10	0	10	5	20	5	15	100
Cat	0	0	0	0	0	0	0	0	0	10	0	0	10
Chipmunk	0	5	0	1070	0	50	0	60	55	0	0	0	1240
Coyote	60	40	75	20	20	5	5	10	16	5	45	25	326
Deer	2420	2530	795	1255	3280	1620	2050	3120	2050	3710	1360	1890	26080
Dog	0	5	5	5	0	0	0	0	0	15	15	15	60
Flying Squirrel	0	0	0	0	0	0	0	5	0	0	0	0	5
Fox Squirrel	0	0	0	0	0	0	5	5	0	0	5	0	15
Grey Fox	0	0	0	0	0	0	0	0	0	0	0	5	5
Groundhog	0	0	35	0	0	0	0	0	0	0	0	0	35
Long Talied Weasel	0	0	5	0	0	0	0	0	0	0	0	0	5
Mouse	20	0	0	35	5	0	30	5	25	0	0	0	120
Opossum	0	25	20	10	0	15	5	15	10	0	20	0	120
Owl	0	5	0	25	5	0	0	0	0	0	0	0	35
Rabbit	50	0	5	25	0	0	0	0	0	0	0	5	85
Raccoon	35	10	0	5	35	55	20	30	25	25	40	30	310
Ruffed Grouse	0	0	5	0	0	0	0	0	0	0	0	0	5
Squirrel	30	0	0	5	0	60	0	50	70	10	80	0	305
Striped Skunk	0	0	0	0	0	0	0	0	0	0	5	0	5
Trespasser	10	100	785	0	0	0	0	0	10	30	0	0	935
Turkey	160	170	15	0	30	15	5	10	0	5	15	15	440
Total	2805	3040	1790	2720	3415	1900	2205	3355	2281	3855	1650	2025	31041

Table 4. Top ranking (ΔAIC < 2.00) occupancy models of White-tailed Deer by season, including probability of detection probability (p), and occupancy (Ψ) for the Tater Hill Plant Preserve, North Carolina, USA, January 2017 – January 2018

	Model	AIC	ΔAIC	AIC Weight	Model Likelihood	# Par.
Winter						
	Ψ(•) *p*(Path,Coyote)	518.60	0.00	0.0855	1.0000	4
	Ψ(•) *p*(Path)	519.99	1.39	0.0427	0.4991	3
	Ψ(Car) *p*(Path,Coyote)	519.99	1.39	0.0427	0.4991	5
	Ψ(Phila) *p*(Path,Coyote)	520.16	1.56	0.0392	0.4584	5
	Ψ(Delph) *p*(Path,Coyote)	520.16	1.56	0.0392	0.4584	5
	Ψ(Geum) *p*(Path)	520.19	1.59	0.0386	0.4516	5
	Ψ(Mert) *p*(Path,Coyote)	520.31	1.71	0.0364	0.4253	5
	Ψ(Path) *p*(Path,Coyote)	520.46	1.86	0.0337	0.3946	5
	Ψ(Boundary) *p*(Path,Coyote)	520.47	1.87	0.0336	0.3926	5
	Ψ(Rare2017) *p*(Path,Coyote)	520.52	1.92	0.0327	0.3829	5
	Ψ(Micr) *p*(Path)	520.53	1.93	0.0326	0.3810	5
	Ψ(Plat) *p*(Path,Coyote)	520.58	1.98	0.0318	0.3716	5

	Ψ(Habitat) *p*(Path,Coyote)	520.59	1.99	0.0316	0.3697	5
	Ψ(Grays) *p*(Path,Coyote)	520.59	1.99	0.0316	0.3697	5
Spring						
	Ψ(Boundary) *p*(Main Rd, Turkey)	637.50	0.00	0.4357	1.0000	5
	Ψ(Boundary, Habitat) *p*(Main Rd, Turkey)	639.33	1.83	0.1745	0.4005	6
Summer						
	Ψ(Card) *p*(Main Rd, Turkey)	920.12	0.00	0.1706	1.0000	5
	Ψ(Boundary) *p*(Main Rd, Turkey)	920.59	0.47	0.1348	0.7906	5
	Ψ(Mert) *p*(Main Rd, Turkey)	920.62	0.50	0.1328	0.7788	5
	Ψ(Micr) *p*(Main Rd, Turkey)	921.56	1.44	0.0830	0.4868	5
	Ψ(Main Rd) *p*(Main Rd, Turkey)	921.74	1.62	0.0759	0.4449	5
	Ψ(•) *p*(Main Rd, Turkey)	922.00	1.88	0.0666	0.3906	4
Fall						
	Ψ(•) *p*(Bobcat, Boundary)	519.32	0.00	0.5137	1.0000	6
	Ψ(Boundary) *p*(Bobcat, Boundary)	521.12	1.80	0.2089	0.4066	5

Abbreviations: • = constant, path = walking paths and main Rd, main Rd = maintenance roads, Boundary = 2017 Tater Hill Plant Preserve boundary, Habitat = Habitat designation code per camera site, Coyote = Coyote (*Canis latrans*) detection rate, Turkey = Turkey (*Meleagris gallopavo*) detection rate, Bobcat (*Lynx rufus*) = Bobcat detection rate, Card = *Cardamine clematitis*, Delph = *Delphinium exaltatum*, Geum = *Geum geniculatum*, Grays = *Lilium grayi*, Phila = *Lilium philadelphicum*, Mert = *Mertensia Virginica*, Micr = *Micranthes pensylvanica*, Plat = *Platanthera grandiflora*, Rare 2017 = nearest distance between camera site and any rare plant distribution based on 2017 updated geographic data

Chapter 3 - The Genetic Diversity of an Invasive Weed Centaurea maculosa in a North Carolina Plant Preserve

The Genetic Diversity of an Invasive Weed *Centaurea maculosa* in a North Carolina Plant Preserve[1]

Byron L. Burrell[2], Matt C. Estep[1,*]

Abstract - *Centaurea maculosa* is an invasive species with allelopathic properties and the ability to displace local flora and fauna. Little is known about the genetic diversity of *C. maculosa* in North Carolina. This study sampled forty individuals from a single population within the Tater Hill Plant Preserve. The study used microsatellite markers and ArcMap to determine the effort needed to decrease or eradicate *C. maculosa* from the Tater Hill Plant Preserve. The average alleles per locus was 5.17, with the number of alleles ranging from 3 to 8. Observed heterozygosity ranged from 0.0417 to 0.9189. Mechanical plant pulls of 700 individuals decrease range expansion by 61%, but range expansion still occurred. Our study indicates that after 15 years of being established in the Tater Hill Plant Preserve, the *C. maculosa* population contains low genetic diversity compared to other populations within its invasive range. This decrease in genetic diversity is likely caused by a founders effect, but with 8 alleles appearing at a single locus, multiple introductions must have occurred. Furthermore, data support the need of extensive weed pulls to manage *C. maculosa* range expansion within the preserve. Overall, this study provides information to support efforts in

[2] Department of Biology, Appalachian State University, Rankin Science Building, 572 Rivers Street, Boone, NC 28608. [*]Corresponding author - estepmc@appstate.edu

monitoring and eradication *C. maculosa* from the Tater Hill Plant Preserve and plant preserves across the region.

Introduction

Centaurea maculosa (Asteraceae), commonly known as Spotted Knapweed originated in Europe with a current native range extending from Western Europe to Western Asia (Dostál 1976), and was first recorded in North America in Victoria, British Columbia in 1893 (Groh 1944). *Centaurea* is thought to have been introduced into the United States as a contaminant to alfalfa seed or soil carried as a ships' ballast (Groh 1944, Müller et al. 1988, Watson and Renney 1974). While the origin of *C. maculosa*'s introduction to North America remains speculative, it had spread throughout Canada and the United States in both alfalfa and hay before it was recognized to be an invasive species (Roche and Roche Jr 1988). Since this realization, *C. maculosa* has been studied heavily to understand how it successfully establishes in new locations, how it displaces native flora, and what effects it may have on native fauna (Emery and Gross 2005, Mummey and Rillig 2006). *Centaurea maculosa* is expanding its range into North Carolina (Miller et al. 2011) and was recently observed within the Tater Hill Plant Preserve of Watauga County, NC (Birdsall, personal communication, October 24th 2015).

Species Genetics

The species concept within the *Centaurea* genus is complicated by infraspecific variation and further complicated by variation in ploidy level (Ochsmann 2000). Some taxonomists describe *C. stoebe ssp. stoebe* L. as diploids and *C. stoebe ssp. micranthos* L. as tetraploids (Ochsmann 2001). Other taxonomists describe *C. stoebe spp. micranthos* as a

distinct species with the name *C. maculosa* (Moore and Frankton 1954). Regardless of the taxonomic complications both species names are consistently referred to as Spotted Knapweed in North America (Ortega and Pearson 2005, Ridenour and Callaway 2001)

Genetic diversity within *C. maculosa* populations in Montana and Colorado was investigated using 9 microsatellite markers (Marrs et al. 2006). The allelic diversity ranged from 6 to 25, suggesting considerable diversity exists in the invasive range. The observed heterozygosity ranged from 0.200 to 0.815 and was lower than expected based on Hardy-Weinberg equilibrium (HWE) predictions (Marrs et al. 2006). Diversity studies comparing allelic richness from the native range (23.7) and those introduced to North America (20.8) suggest that multiple introductions have occurred based on genetic diversity measures and the structure of populations (Marrs et al. 2008).

Weed management review

Evaluation of weed control strategies for *C. maculosa* have been conducted for more than half a century (Harris and Cranston 1979). Results have indicated that management strategies such as burning, cultivation, and fertilization have had little to no effect on *C. maculosa* populations (Sheley et al. 1998). Weed management strategies that have been demonstrated to have an effect on *C. maculosa* populations are methods such as biologic controls, herbicides, and hand pulling methods (Sheley et al. 1998). Many of these strategies can easily be used within rangeland settings but the use of biologic controls and herbicides within the rare plant preserve can be concerning. A problem stemming from the use of biologic control is the potential of the control agent to effect unintended plants. One instance in which this has occurred is the seed-eating weevil *Larinus planus* on the federally threatened Pitcher's thistle (*Cirsium pitcher*) (Havens et al. 2012). In regards to herbicides,

the concern that persists is the potential cost associated. Results have shown that while herbicides may be effective at reducing *C. maculosa* flowering individuals, there is still potential for seed production from these indivudals to occur (Sheley et al. 2000). The combination of herbicide use along with *C. maculosa* extensive seed bank makes herbicide use potentially not cost effective. The final method showing effects on decreasing *C. maculosa* is hand pull methods. The hand pulling method provides a means to which focused eradication can occur without potential for effects on unintended plants. In addition the cost of this method is low in comparison to potential herbicide use, however, the amount of effort needed to decrease *C. maculosa* spread or completely eradicate from an area is unknown (Griffith and Lacey 1991). *C. maculosa* has a deep taproot that should also be removed during extraction (Winston et al. 2015) Hand-pulling entire plants has been shown to control small infestations of C. maculosa (Sheley et al. 1998).

This study aims to, 1) examine the genetic diversity of *C. maculosa* within the Tater Hill Plant Preserve, 2) determine whether this population represents a single or multiple introductions, 3) examine the rate of spread of *C. maculosa*, and 4) examine the effort needed to eradicate or halt range expansion within the Tater Hill Plant Preserve.

In many situation, the introduction of a species to a new area creates a population with decrease genetic diversity, also known as a founders effect. If a population experiences multiple introduction over time then this could bolster genetic diversity and increase potential of invasive species success (Dlugosch and Parker 2008). Understanding genetic diversity along with number of introductions can inform land managers of the precedence to monitor and eradicate *C. maculosa* within the preserve. If *C. maculosa* has experienced multiple introductions, then resources should be focused on understanding how *C. maculosa* invaded

the preserve and subsequently keep it from happening again. If *C. maculosa*'s invasion into the preserve is determined as a stochastic event, then management resources can be focused elsewhere. It has been said that prevention is far more cost-effective then remediation when dealing with invasive species (Mack et al. 2000, Miller et al. 2005). Understanding the rate of spread for *C. maculosa* can inform management to what practices are having the greatest effect, while eliminating *C. maculosa* from the Tater Hill Plant Preserve through weed pulls will assist in eliminating genetic potential if more introductions occur in the future.

Field-Site Description

The Tater Hill Plant Preserve is a 486-hectare preserve located in northwest Watauga County, NC and has been owned operated by the North Carolina Department of Agriculture's Plant Conservation Program since August of 2000. The preserve currently protects more than 20 rare and state listed species of plants over a multitude of habitats. The Tater Hill Plant Preserve habitats range from high elevation rock outcrops, rich cove forests, northern hardwood forests, to a mountain bog ecosystem. Elevation within The Tater Hill Plant Preserve ranges between 1,082 meters to 1,644 meters and preserve boundaries stretch for approximately 5.6 km at its longest and 1.52 km at its widest. The preserve has a few designated maintenance roads with several old logging paths used for walking trails by management.

Methods

Collections

A North Carolina Department of Agriculture's Plant Conservation Program species collection permit was acquired (per. Comm. Estep). Forty unique individuals were randomly sampled from the entire population within the Tater Hill Plant Preserve during August of

2016. This population is the only known occurrence of *C. maculosa* within the preserve, and currently covers approximately 0.43 hectares. Rough estimates suggest a total of 5000 individuals within this population (per Obs. Burrell). A leaf from each sampled plant was collected and stored in silica gel (Sigma-Aldrich 294316) with long-term storage in an -80 C freezer.

DNA extraction

Leaf tissue was ground to a fine powder using approximately 100 mg of autoclaved sand and a micro-pestle. DNA was extracted from powdered tissue using a modified cetyltrimethylammonium bromide (CTAB) method (Doyle 1987). DNA was quantified using a Nano-drop 1000 (Thermo Fisher Scientific, Waltham, MA, USA) and examined for quality using a 1% TBE agarose gel.

Genotyping

DNA was diluted to 20 ng/ul and arrayed into a 96 well plate. Eight duplicate samples were included to bring the total number of samples to 48 to ensure accurate genotyping. Eight polymorphic microsatellite markers (25CM6, CD9, CM15, CM17, 38CM22, CM26, 42CM27, and 21CM36), were used to score genotypes following the published thermocycler conditions (Marrs et al. 2006). An M13 tag (5'-CACGACGTTGTAAAACGAC-3') was added to the 5' end of each forward primer to facilitate labeling PCR products with one of four fluorescent dyes (FAM, VIC, NED, or PET) following methods by Schuelke (2000). PCR products with different dye's were multiplexed and then separated on an ABI3730 sequencer using Hi-Di and a GeneScan Liz 500 size standard (Applied Biosystems, Foster City, California, USA). Resulting chromatograms were assessed in Geneious 9.0.5

(Biomatters, Auckland, New Zealand). Individuals were scored with the potential of four distinct peaks, as *C. maculosa* is a tetraploid.

Statistics and Analysis

Basic descriptive statistics including the number of alleles per locus, total number of alleles, and the allelic ranges where calculated in Microsoft Excel (Redmond, Washington, USA). Expected heterozygosity (H_E) for each locus was calculated using SPAGeDi 1.3a (Hardy and Vekemans 2002), and observed heterozygosity (H_O) was calculated by hand similar to Mars (2006). Statistical comparisons of heterozygosity should be interpreted with caution since it is unknown if *C. maculosa* is autopolyploid or allopolyploid (Dufresne et al. 2014).

Area and Weed Control

The area inhabited by *C. maculosa* on the Tater Hill Plant Preserve was calculated by taking waypoints of plants on the outskirts of the current population using a Garmin 64st (Garmin, Olathe, Kansas, USA). Waypoint data were then imported into Garmin Basecamp software (4.6.2), exported as a gpx file, and then loaded into ArcMap (10.3.1) (Esri, Redlands, CA, USA). Area was measured using an area measure tool within ArcMap. Total area was recorded and calculated in August of 2016, and August of 2017 before the population was manipulated with weed pulls.

Hand-pulling of *C. maculosa* occurred when individuals began to flower during August of 2016 and in late July of 2017.Approximatly 700 plants were pulled in a single day of 2016, were as 600 plants were pulled once a week for five consecutive weeks in an effort to remove all observed plants during 2017.

Results

A total of 38 individuals were successfully genotyped across six microsatellite markers. Markers CD9, CM15, and 38CM22 displayed a diploid pattern of inheritance with no more than two alleles identified per individual. Markers 25CM6, CM26, and 42CM27 displayed a tetraploid inheritance patterns with no more than 4 alleles identified per individual. The number of alleles observed per locus ranged from 3 to 8, with an average of 5.17 alleles per locus and a total number of 31 across the six markers (Table 5). Observed heterozygosity ranged from 0.0417 to 0.9189 with the majority (66%) exceeding the expected heterozygosity based on the number of alleles observed and HWE proportions (Table 5.) Those markers that displayed a tertraploid inheritance pattern always had a higher observed heterozygosity than expected.

During August of 2016 a total of ~700 individuals were removed from the population. In July and August of 2017 an additional ~2700 individuals were removed. The calculated area for *C. maculosa* in 2016 was 0.426 hectares, while the area in 2017 was 0.439 hectares.

Discussion

Genetic Diversity

This study of genetic diversity in *C. maculosa* is the first to examine a small population on the east coast of the United States where *C. maculosa* is known to be expanding its range (Miller et al. 2011). The average allelic diversity observed on the plant preserve (5.2 alleles per locus) was much lower than reported for the species in its native range of Europe (23.7 alleles per locus) or in North America (20.8 alleles per locus) (Marrs et al. 2008). This reduction in diversity is likely caused by founder effects, but could also be influenced by the small number of individuals genotyped in comparison to larger studies where multiple

populations were sampled (Marrs et al. 2008). Even in smaller studies where only 229 individuals were sampled the average allelic richness of 14 alleles per locus was almost 3 times greater than observed in our sample of 38 individuals (Marrs et al. 2006). We identified more than 4 alleles in the population on the preserve at three loci (M6, M26 & M27), suggesting multiple introductions, or a single introduction of multiple individuals.

A second measure of diversity is heterozygosity, which is insensitive to sample size but can be difficult to interpret in polyploidy species like *C. maculosa* (Allendorf et al. 2013). The software SPAGeDi assumes polysomic inheritance in polyploidy taxa, but these values should be interpreted with caution when comparing to other species because it is unknown if *C. maculosa* is an auto- or allopolyploid which can influence the results (Hardy and Vekemans 2002, Marrs et al. 2008). Comparisons between populations of the same species that were analyzed using the same approach should not be problematic. We observed high heterozygosity values ranging from 0.0417-0.9189, suggesting the population does contain moderate levels of genetic diversity (Table 5). These values are similar to other introduced populations within North America (0.61-0.81) as well as European populations (0.52-0.86) (Marrs et al. 2008). This amount of diversity suggests the population on the preserve did not suffer from a strong bottleneck when it was founded and that multiple introductions or at least multiple individuals were involved.

Area and Weed Control

After *C. maculosa* was identified on the preserve in 2015, further investigation identified a specimen in the Appalachian State University Herbarium collections of the Tater Hill Plant Preserve. Alex Martin collected a specimen in August of 2003 (#29875) in the same location that our population currently resides. The herbarium sample means the introduced population

has been invading the preserve for at least 15 years. Based on 2016 distribution (0.426 hectares), *C. maculosa* has been expanding at roughly 0.03 hectares per year. After we conducted a weed pull in 2016 we estimated an increase of only 0.013 hectares during the 2017 growing season. The increase of 0.013 hectares potentially means that a weed pull of 700 plants was able to reduce yearly expansion by 0.02 hectares per year or approximately 61%. Though we do not have results of 2018 at this time, we speculate that the weed pull of ~2700 individuals in 2017 will cause a decrease in the overall expansion of *C. maculosa* along with possible decreases in overall coverage area.

In order to completely eradicate *C. maculosa* from the preserve, yearly weed pulls and observations will need to continue for at least a decade because the species has been shown to persist with a substantial seed bank even after seven years (Davis et al. 1993). Continued management by mechanical weed pulls will assist in the overall eradication of *C. maculosa* in the Tater Hill Plant Preserve without the need of herbicides.

Management

The presence of *C. maculosa* within the Tater Hill Plant Preserve is alarming and places pressure on land managers and stewards to act for the betterment of the preserve. The results of this study inform land managers that over the course of 15 years that multiple introductions have occurred. If further introductions occur this could result in increasing evolutionary potential allowing for greater spread (Lavergne and Molofsky 2007). While *C. maculosa* is still exhibiting the results of a founders effect this provides an ample opportunity to eradicate *C. maculosa* from the preserve before another introduction occurs. The results of our plant pull indicated that greater than 700 individuals must be pulled to see a decrease in current *C. maculosa* area within the Tater Hill Plant Preserve.

Conclusion

Our study indicates that *C. maculosa* was established on the Tater Hill Plant Preserve over 15 years ago and likely included multiple introductions. Annual weed pulls are an important management strategy, but conservation stewards need educate visitors to reduce the chance of further introductions. In addition, the results of the 2018 area distribution may allow more accurate measures of approximately how many flowering individuals need to be pulled to see a decrease in *C. maculosa* expansion or potential range reductions. While this population was first established before 2003, its area has only expanded to 0.426 hectares. This information advises management and conservation stewards of potential strategies to eradicate and remove *C. maculosa* from the Tater Hill Plant Preserve.

Acknowledgement

The use of any trade, product or firm names does not imply endorsement by North Carolina government. The North Carolina Department of Agriculture Plant Conservation Program provided logistical support along with assistance in weed pulls during the course of this study. Field assistance was also provided by members of Dr. Estep's lab at Appalachian State University. Our study was supported by Appalachian State University Office of Student Research.

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Tables

Table 5. Descriptive Statistics of Genetic Diversity within the *Centaurea maculosa* Population of the Tater Hill Plant Preserve; locus name, number of alleles observed, and observed (H_O) and expected (H_E) heterozygosity for each locus

Marker	No. of alleles	H_O	H_E
25CM6	6	0.8333	0.7733
CD9	3	0.0417	0.5513
CM15	3	0.4571	0.5186
38CM22	4	0.7037	0.6541
CM26	8	0.9142	0.7901
42CM27	7	0.9189	0.7664
Mean	5.17	0.6448	0.6756

Tables

Table 1. Rare and endangered plants of the Tater Hill Plant Preserve; species names, (*) signifying species of historical record, current conservation status and rank, display of coordinate data prior to 2017, and coordinate date updated after 2017 surveys, and results individual flowering counts

	Historical Record	Status		Rank		Mapped		Count
Name		**N.C.**	**U.S.**	**N.C.**	**Global**	**Previous**	**2017**	**2017**
Aconitum reclinatum		SR-T		S3	G3			0
Cardamine clematitis		SR-T		S2S3	G3		X	88
Carex baileyi		SR-P		S2	G3G4			0
Carex roanensis		SR-T		S2	G2G3			0
Carex trisperma		E		S1	G5	x		0
Carex woodii		SR-P		S3	G4			0
Chelone cuthbertii		SC-V		S3?	G3			0
Chelone obliqua		SR-T		S2	G4			0
Corallorhiza maculate var. maculate	*	SR-P		S2	G5T5			0
Delphinium exaltatum		E		S2	G3	x	X	1301
Geum geniculatum		SC-V	FSC	S1S2	G2	x	X	5
Ilex collina		SC-V		S1	G3	x		0
Lilium grayi		T	FSC	S3	G3	x	X	1244
Lilium philadelphicum		E		S2	G5T4T5	x	X	52
Lonicera canadensis		SR-P		S2	G4			0
Meehania cordata		SR-P		S2	G5		X	1
Mertensia virginica	*	W7		S2	G5		X	>1000
Micranthes pensylvanica		E		S1	G5	x	X	34
Packera crawfordii		SR-T		S1	G2G3			0
Packera schweinitziana		T		S2	G5?	x		0
Platanthera flava var. herbiola		SR-P		S1?	G4T4Q			0
Platanthera grandiflora		T		S2	G5	x	x	0
Polemonium reptans var. reptans	*	T		S1	G5T5			0
Turritis glabra		E		S1	G4G5			0
Vaccinium macrocarpon		T		S2	G5			0

Figures

Figure 1. The 2017 Tater Hill Plant Preserve boundaries with Grassy Bald habitat, the Tater Hill Bog, gate locations, common meeting area “oak tree”, walking paths, maintenance roads, streams, 200 m by 200 m grids, and contour lines set in 100ft increments

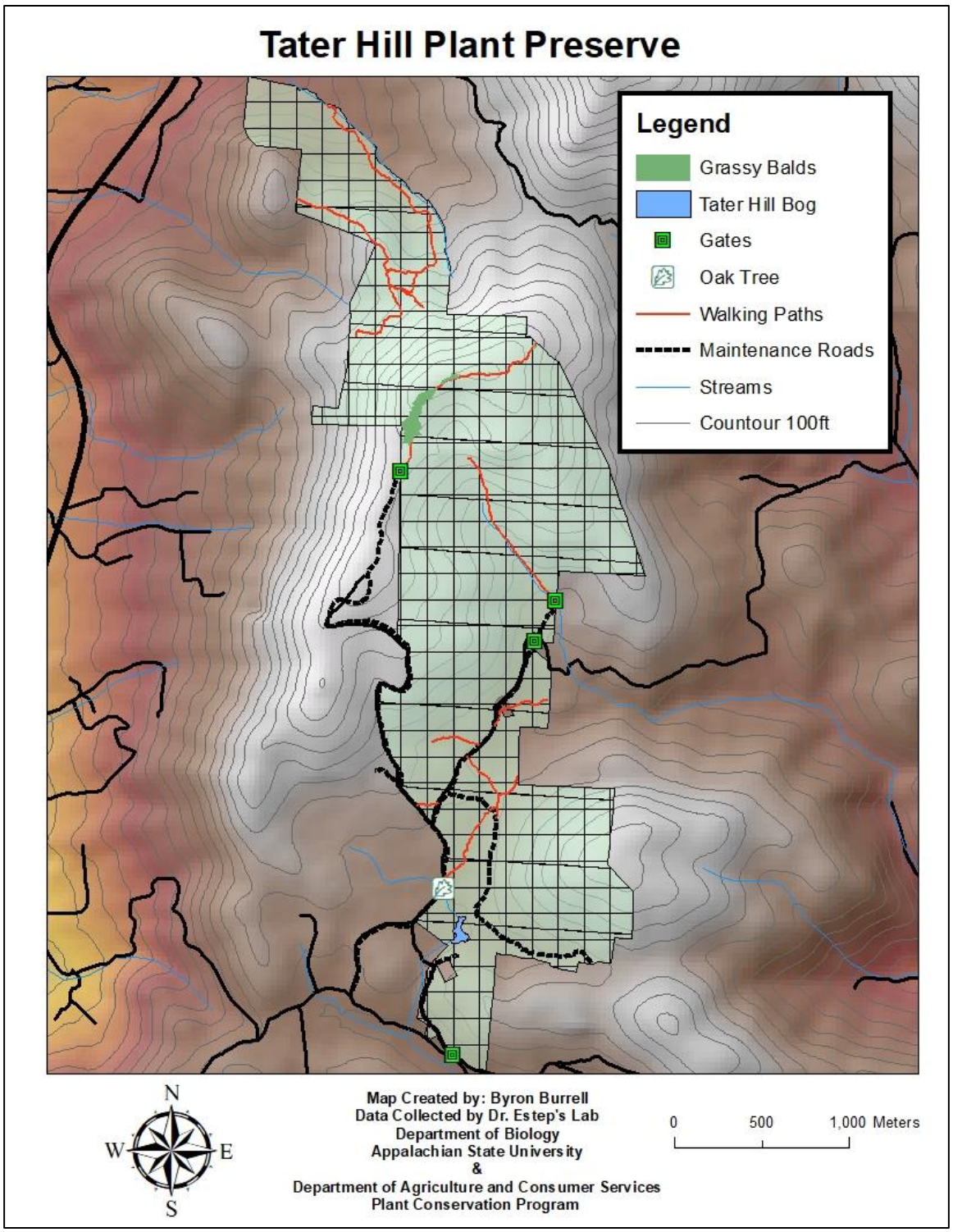


Figure 2. The geographic distribution of Cardamine clematitis within the Tater Hill Plant Preserve based on 2017 wandering surveys

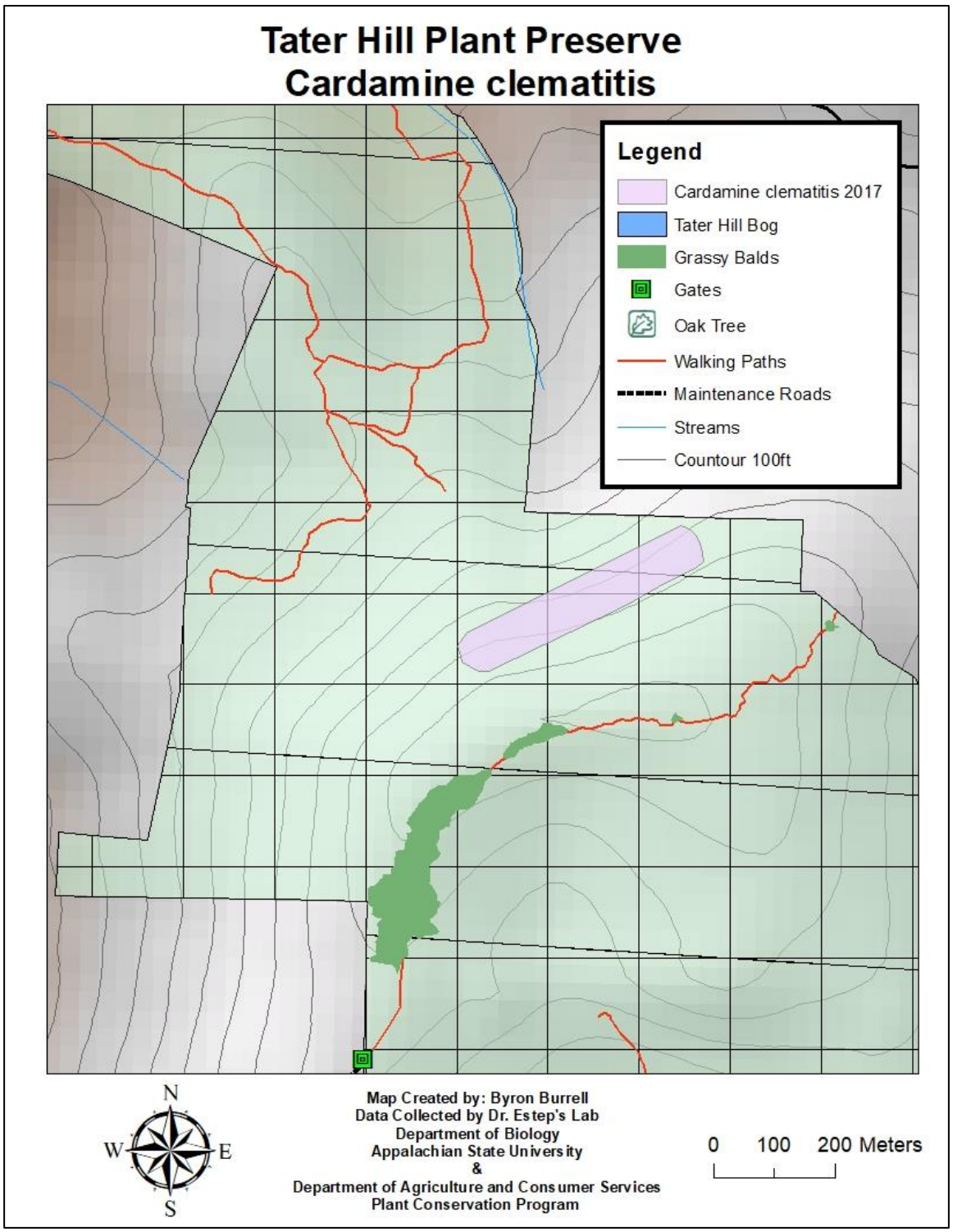


Figure 3. The geographic distribution of Chelone species within the Tater Hill Plant Preserve per 2017 based on wandering surveys

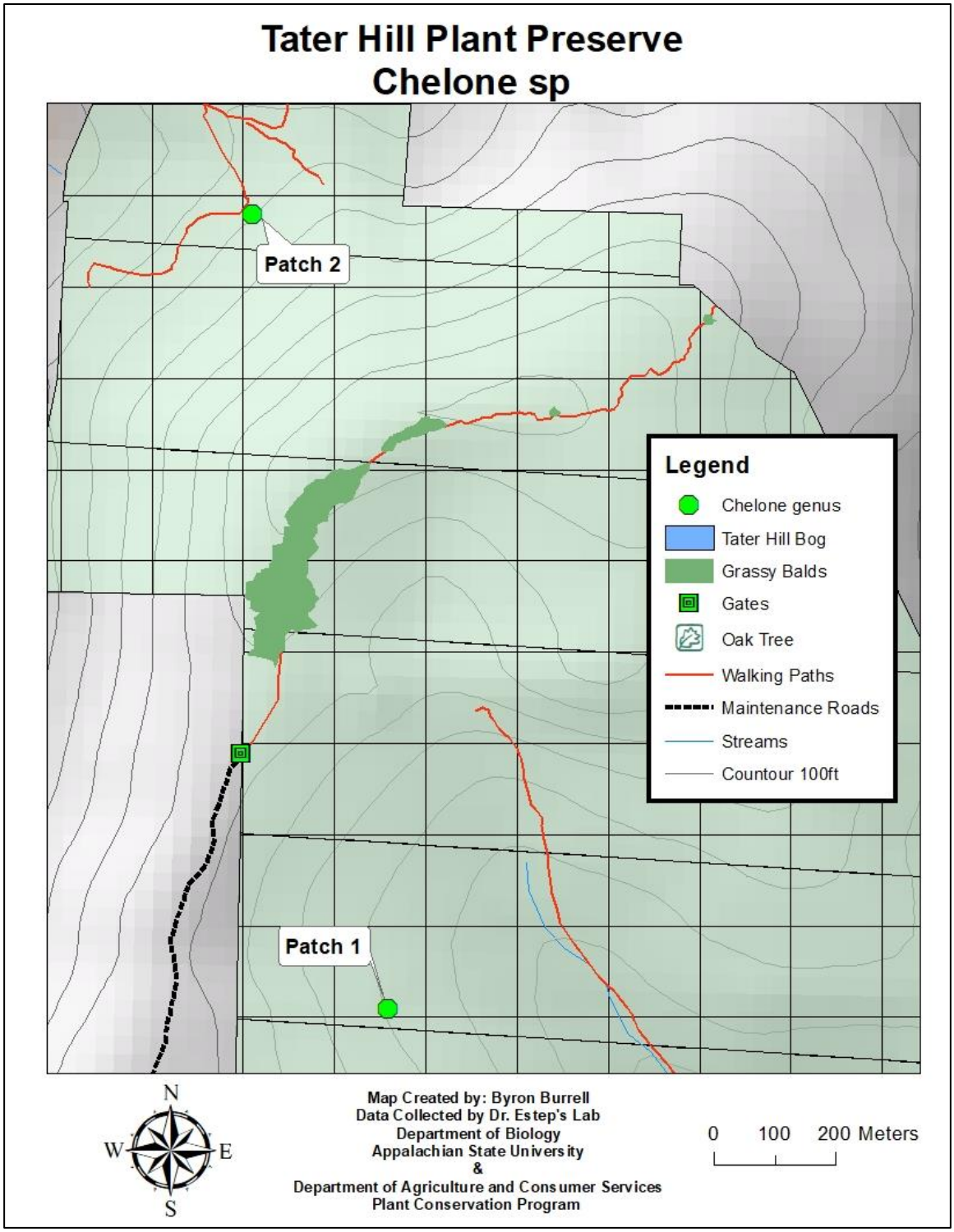


Figure 4. The geographic distribution of *Delphinium exaltatum* within the Tater Hill Plant Preserve based on 2017 wandering surveys

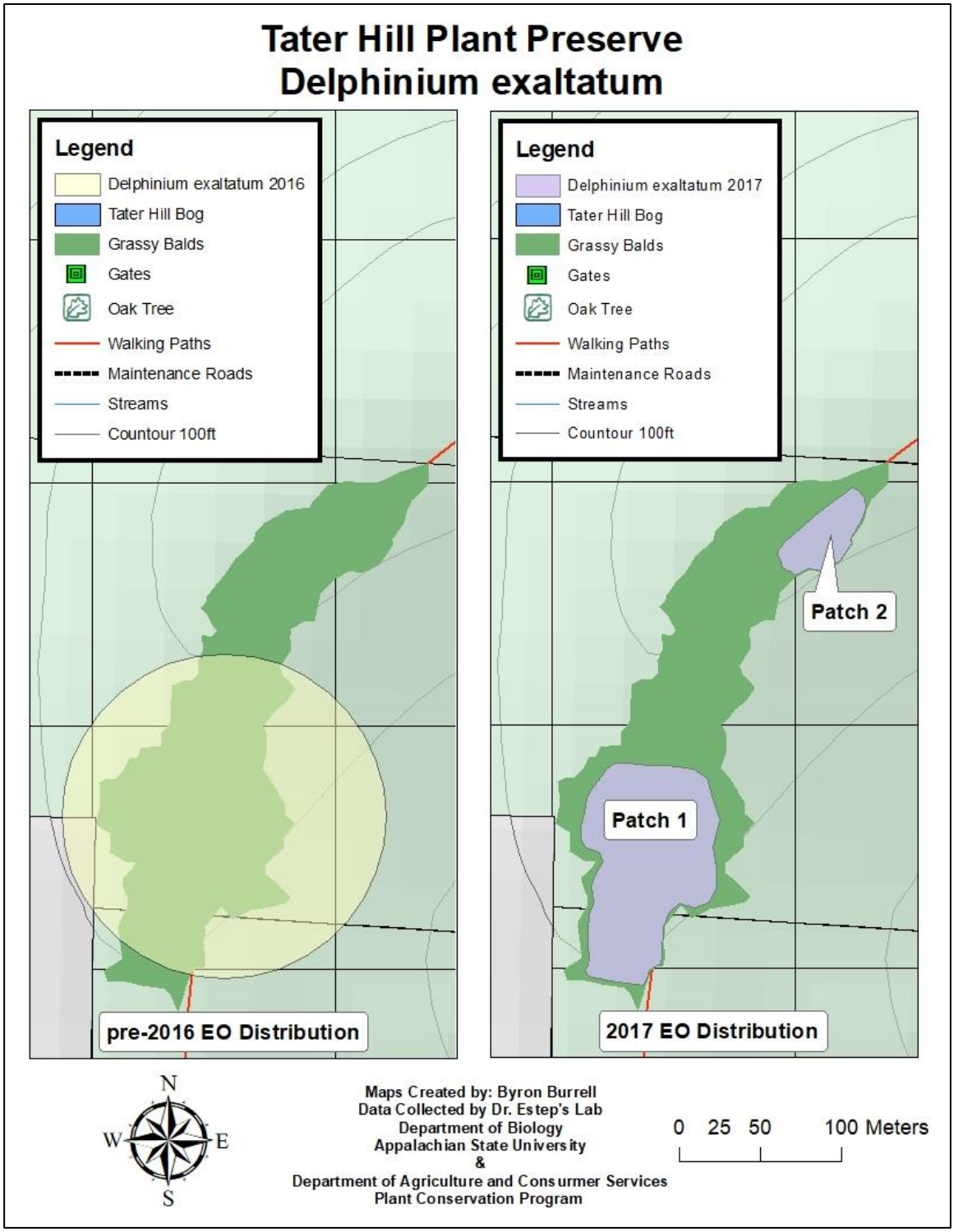


Figure 5. The geographic distribution of *Geum geniculatum* within the Tater Hill Plant Preserve based on 2017 wandering surveys

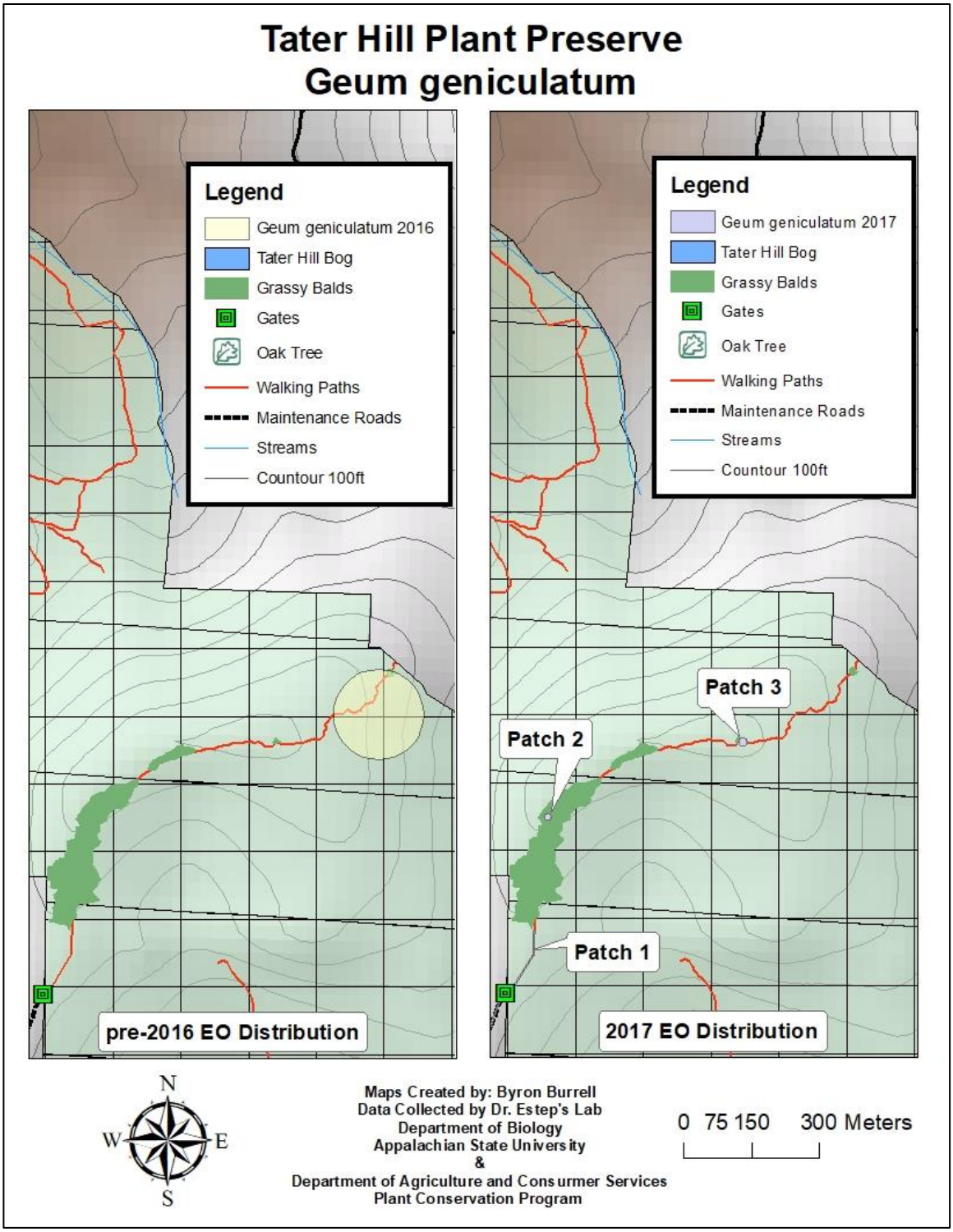


Figure 6. The entire distribution of *Lilium grayi* within the Tater Hill Plant Preserve based on 2016 coordinate data

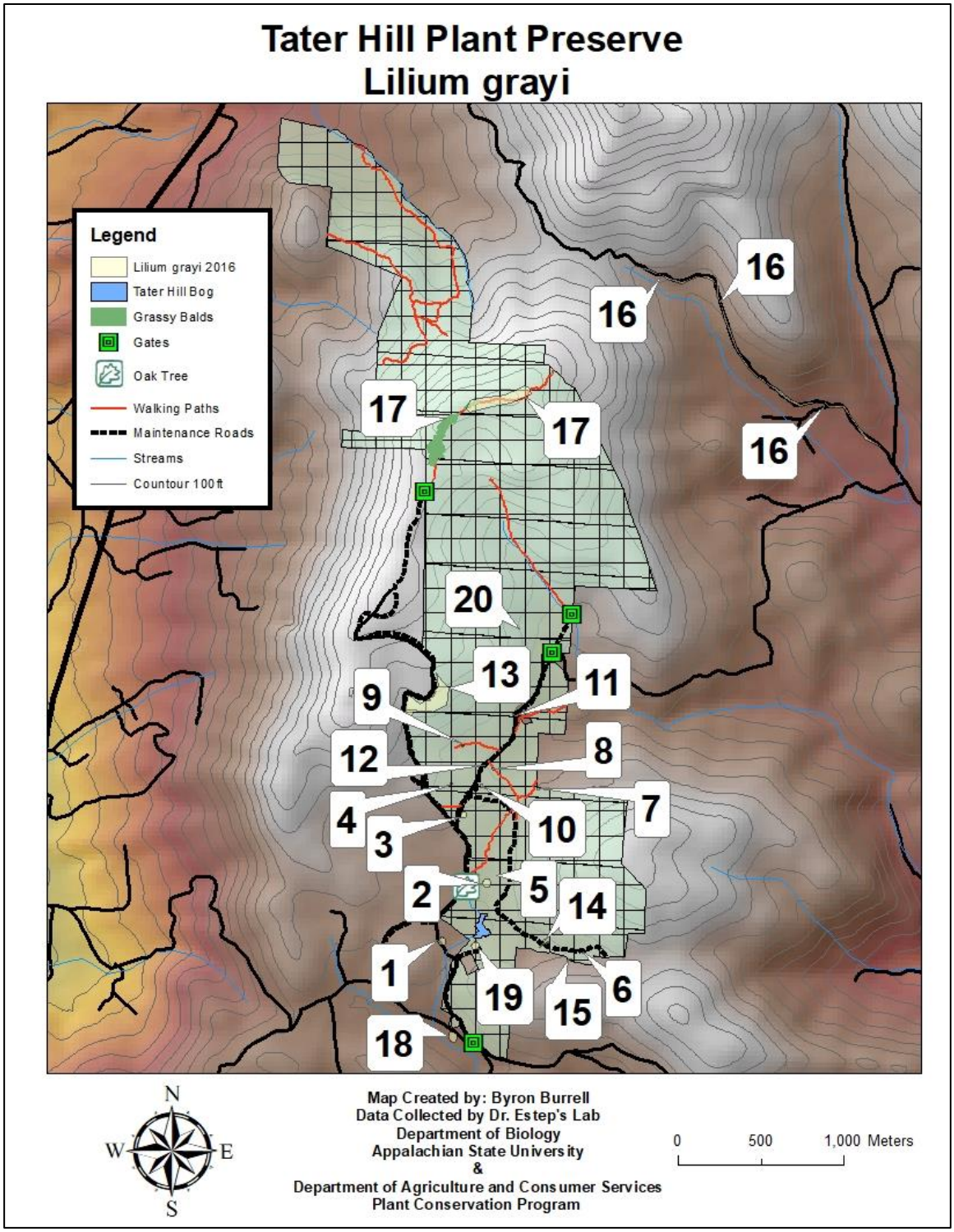


Figure 7. The southern geographic distribution of *Lilium grayi* within the Tater Hill Plant Preserve based on 2017 surveys

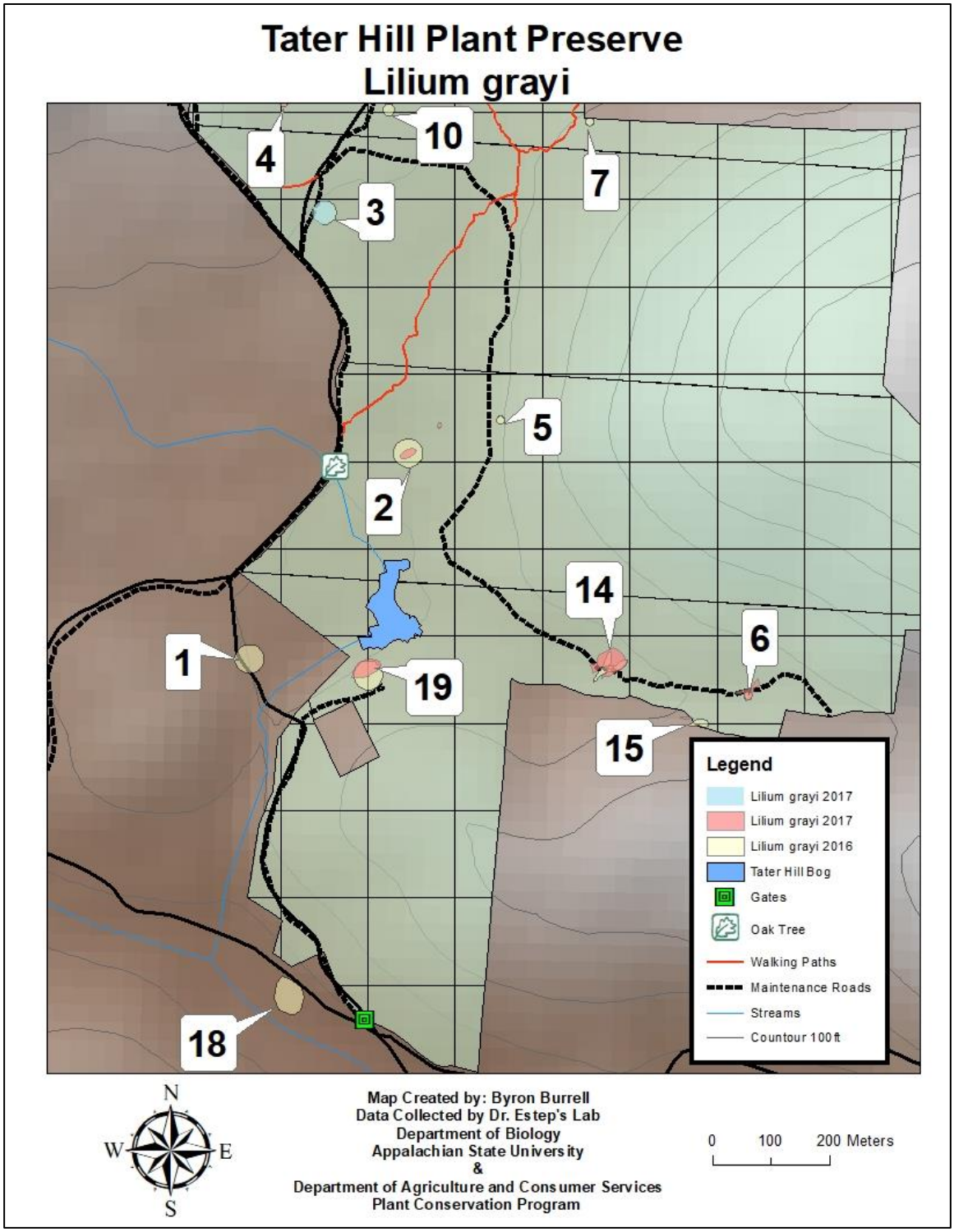


Figure 8. The central geographic distribution of *Lilium grayi* within the Tater Hill Plant Preserve based on 2017 surveys

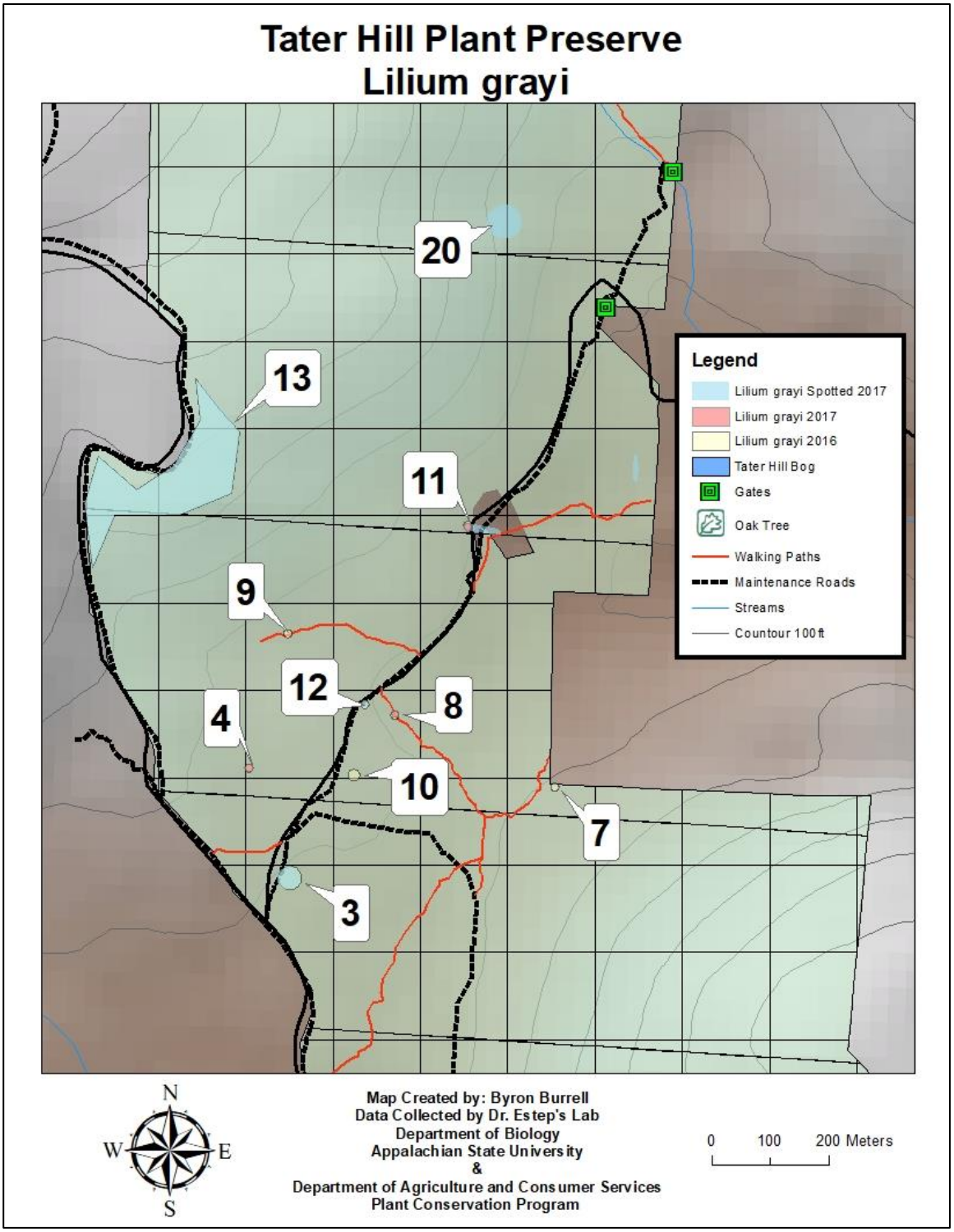


Figure 9. Herbivory by Formicidae (ants) observed on *Lilium grayi* of Patch 6 within the Tater Hill Plant Preserve based on 2017 surveys

Figure 10. The northern geographic distribution of *Lilium grayi* within the Tater Hill Plant Preserve based on 2017 surveys

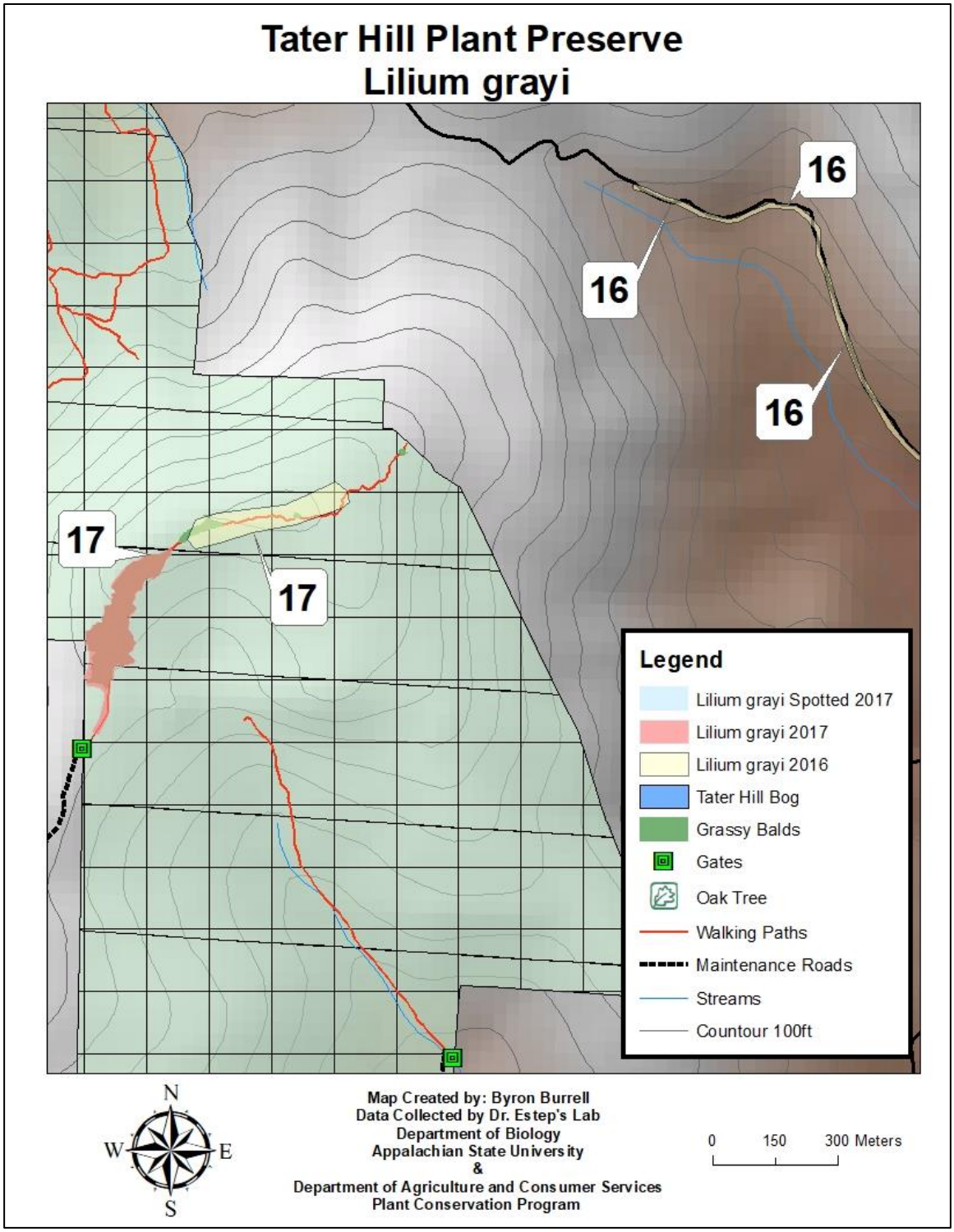


Figure 11. Herbivory by White-tailed deer (*Odocoileus virginianus*) and other unknown species observed in Patch 20 within the Tater Hill Plant Preserve based on 2017 surveys

Figure 12. Confirmed presence of *Pseudocercosporella inconspicua* (Lily Leaf Spot Disease) by Cindy Bennet (East Tennessee State University) within the Tater Hill Plant Preserve based on 2017 surveys

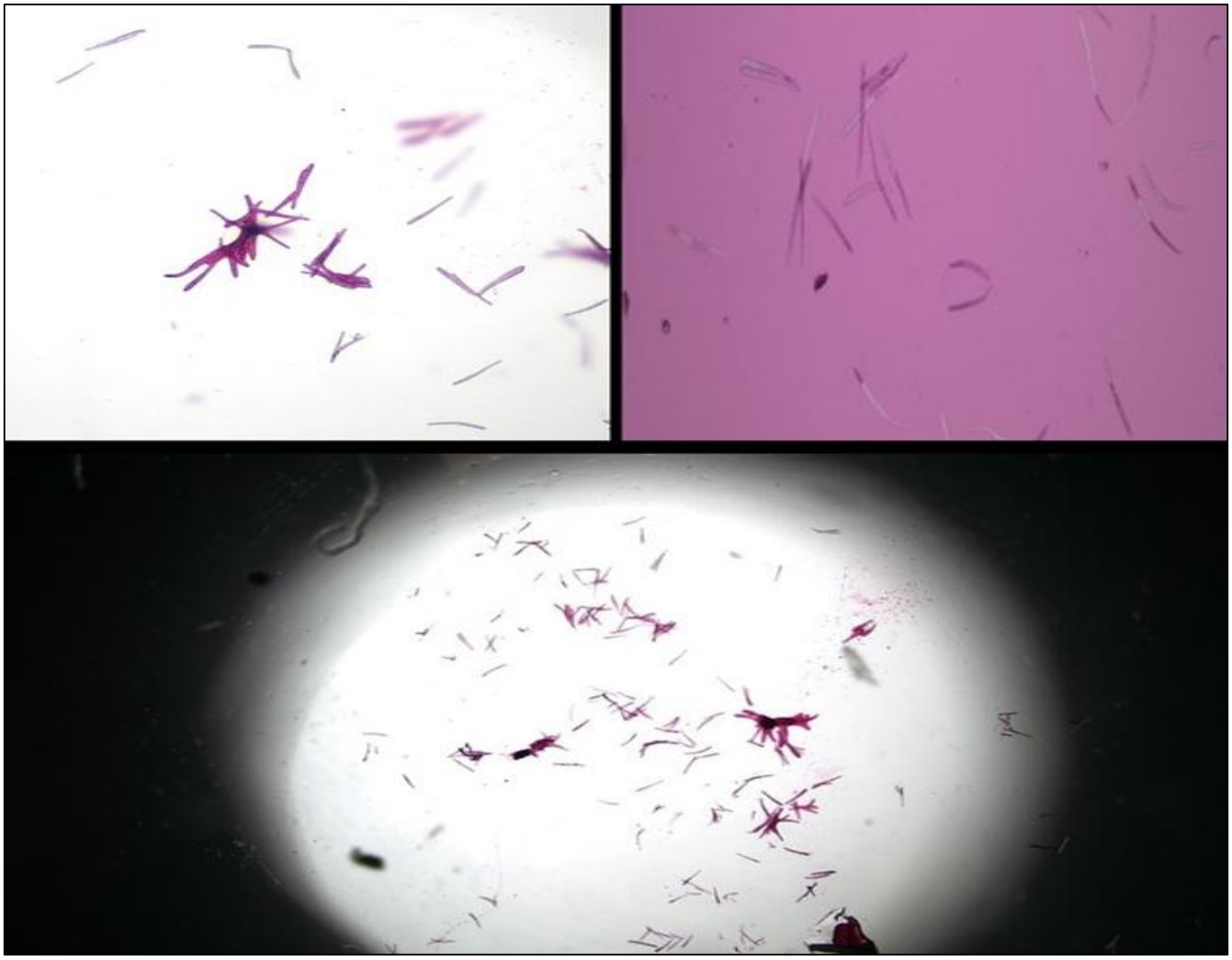


Figure 13. The geographic distribution of *Lilium philadelphicum* within the Tater Hill Plant Preserve based on 2017 surveys

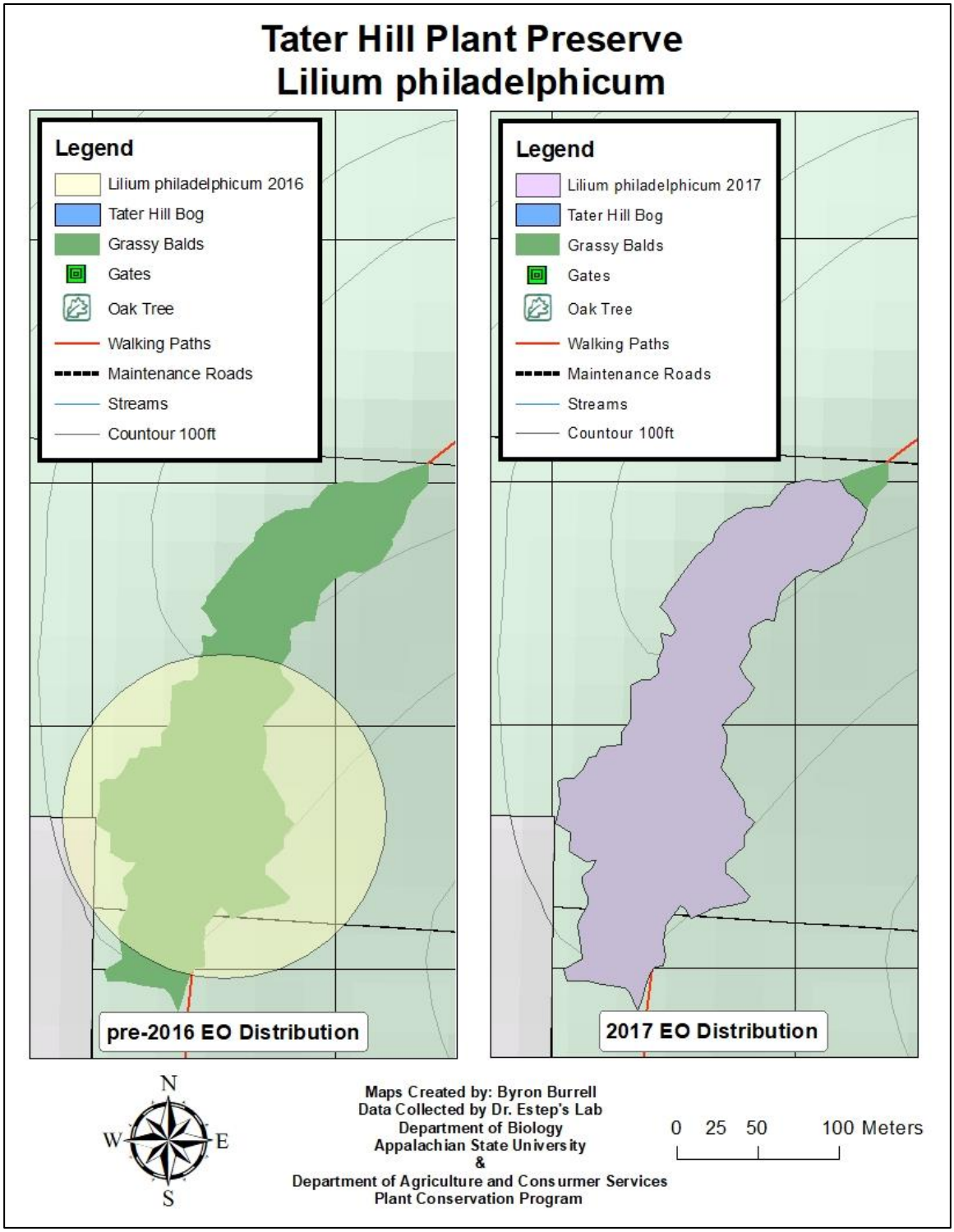


Figure 14. The geographic distribution of *Meehania cordata* within the Tater Hill Plant preserve based on 2017 wandering surveys

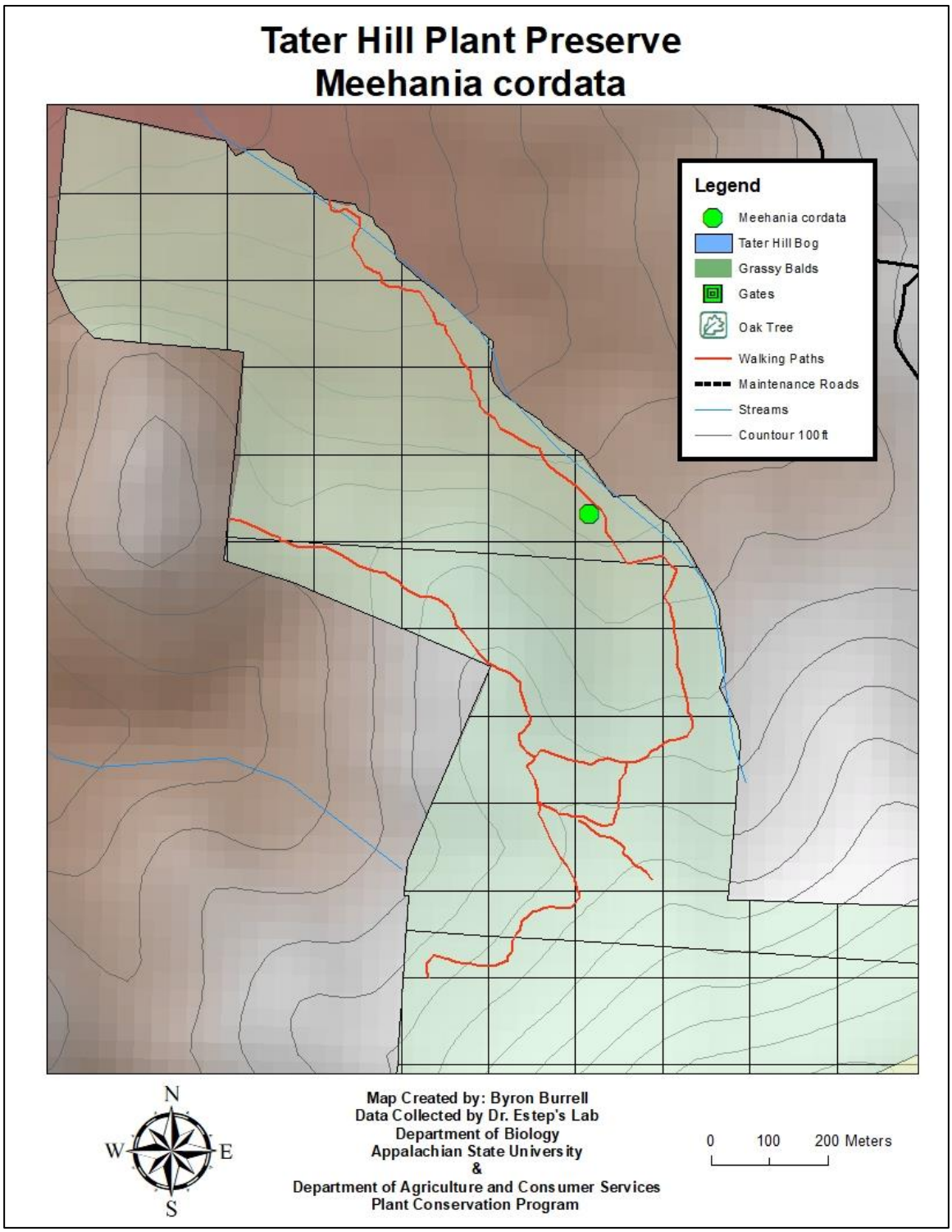


Figure 15. The geographic distribution of *Mertensia virginica* within the Tater Hill Plant Preserve based on 2017 wandering surveys

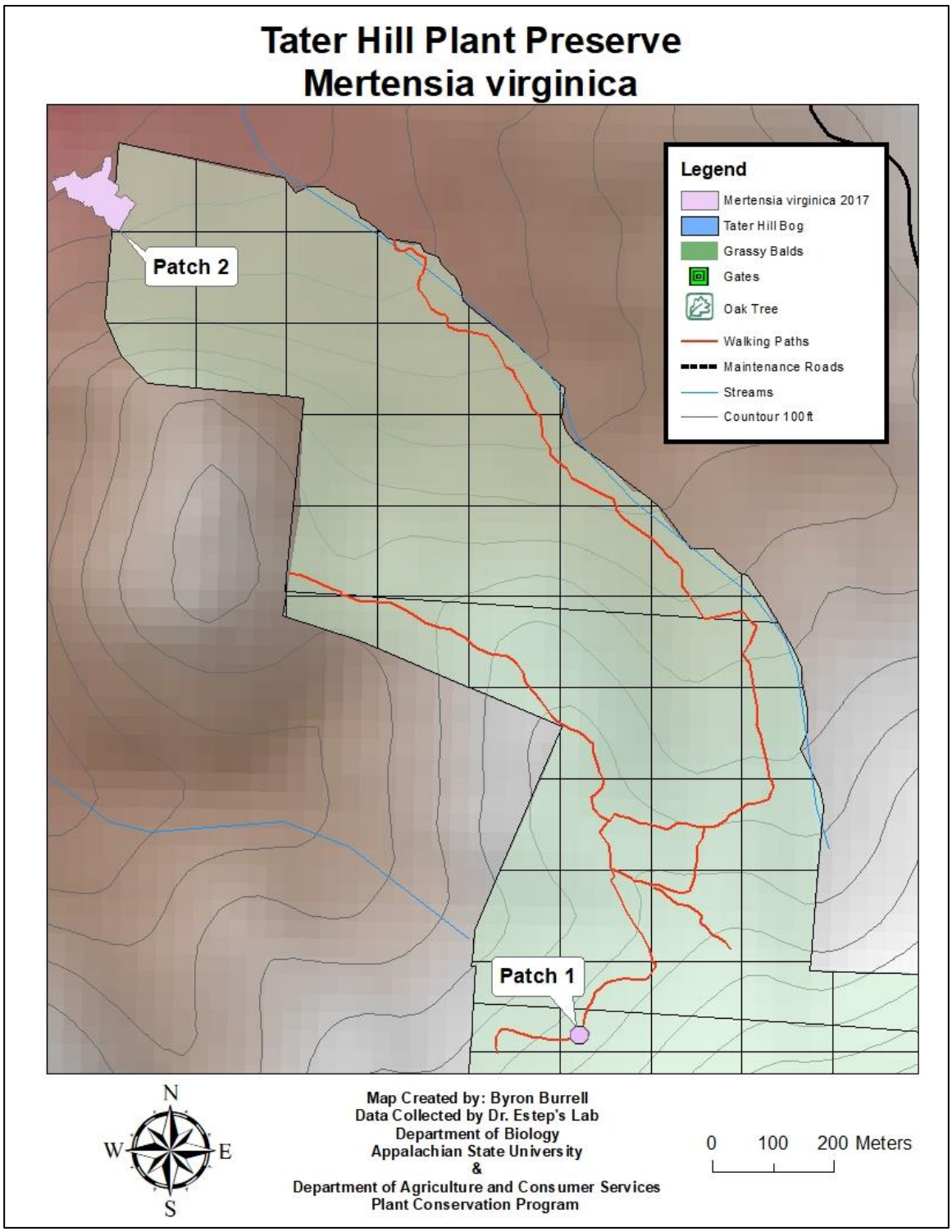


Figure 16. The geographic distribution of *Micranthes pensylvanica* within the Tater Hill Plant Preserve based on 2017 wandering surveys

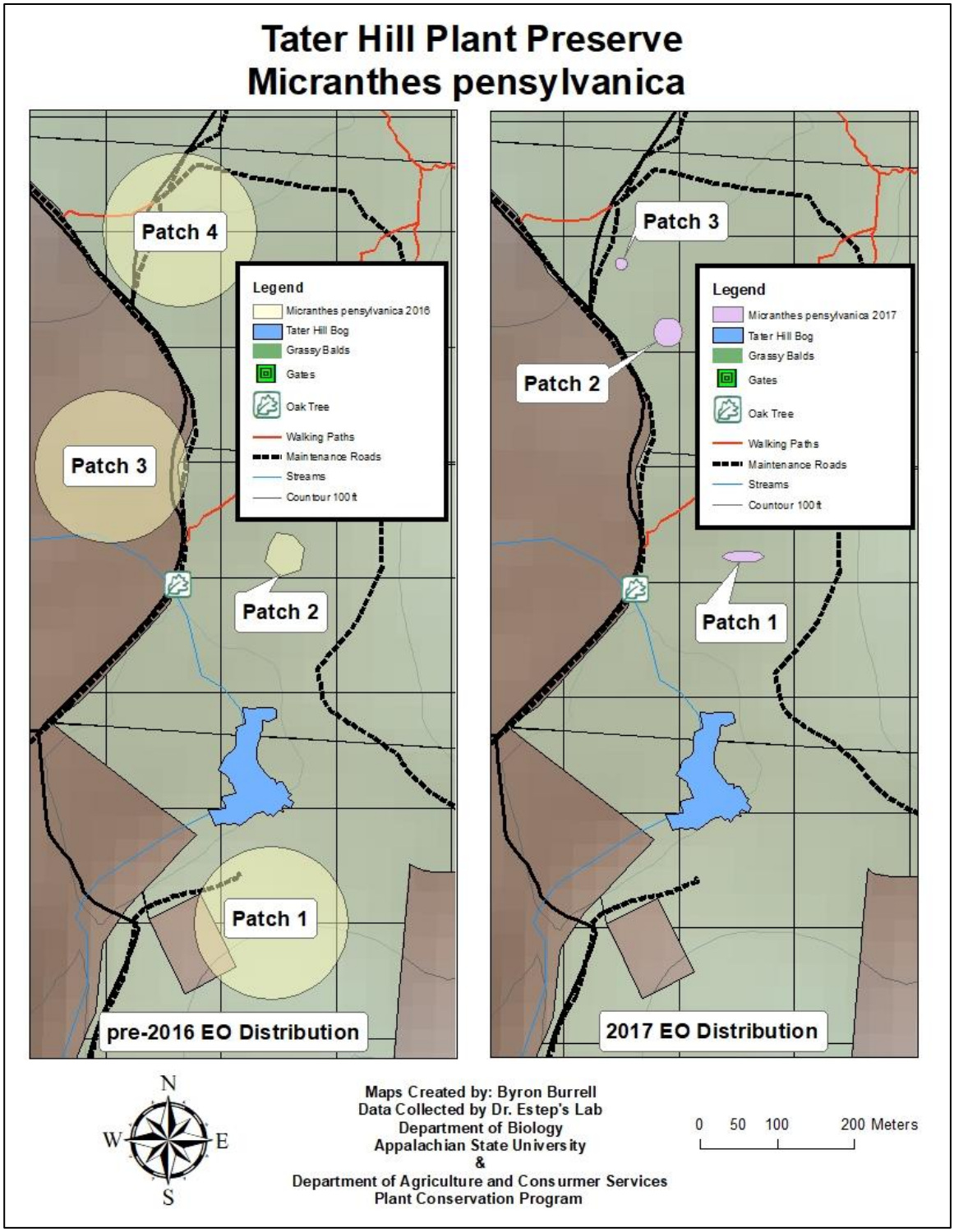
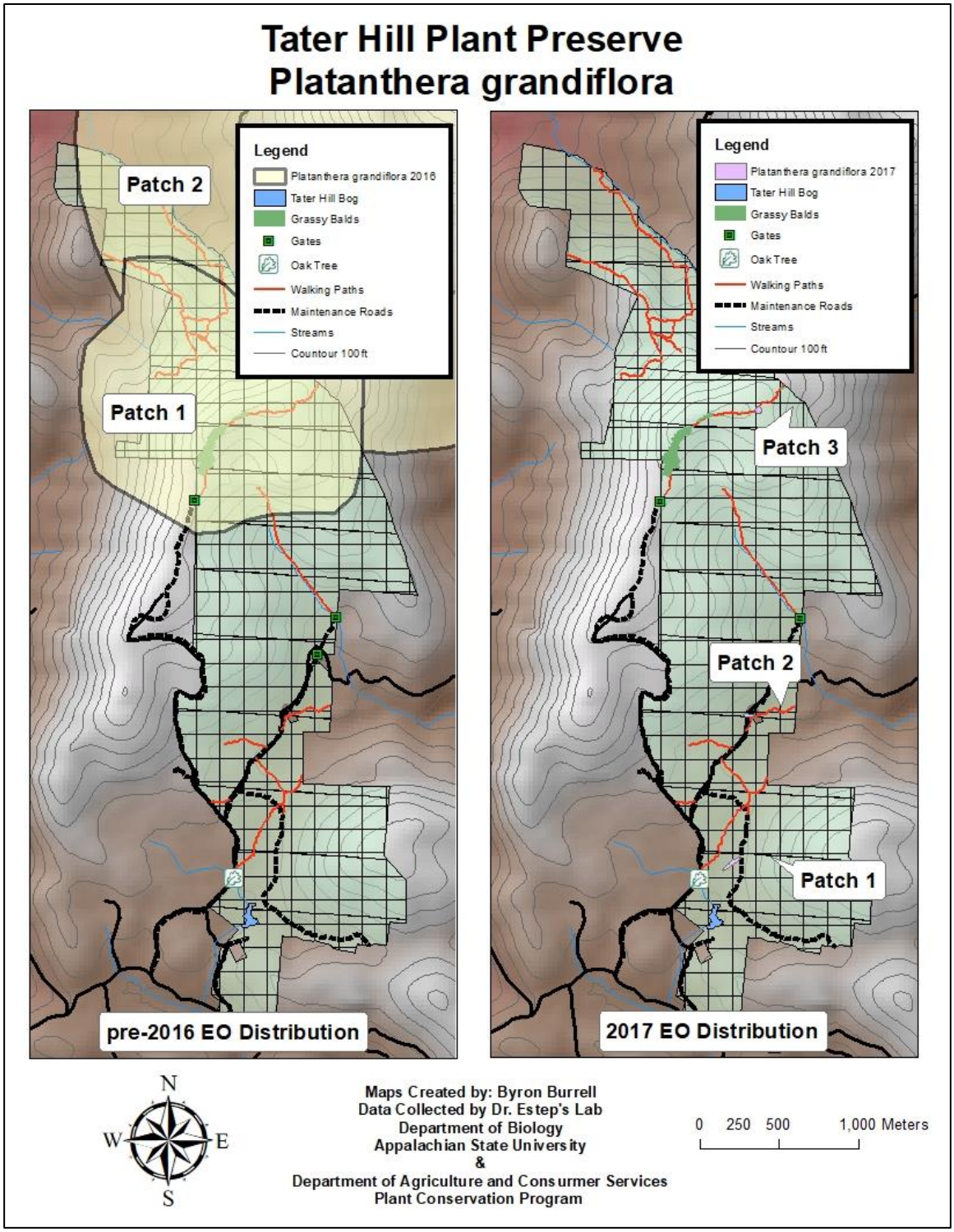


Figure 17. The geographic distribution of *Platanthera grandiflora* within the Tater Hill Plant Preserve based on 2017 wandering surveys



Vita

Byron L. Burrell was born in Iredell County to Roger and Teresa Burrell. He graduated from Appalachian State University in North Carolina in August 2018. Byron hopes to one day be a conservation biologist with the U.S. Fish and Wildlife Service or with the North Carolina Wildlife Resource Commission. He was awarded his Bachelors of Science degree in Biology with a concentration in Ecology, Evolution, and Environmental biology in May of 2015. After graduation, he went to work in Yellowstone National Park where he discovered his passion for large mammals. He returned to Appalachian State University in the fall of 2016 to complete a Masters in Science focusing on Biology with a concentration in Ecology and Evolution.

Mr. Burrell is a member of National Wild Turkey Federation, The Wildlife Society, and several other wildlife conservation organizations, and remains active in supporting conservation goals.