

HISTORY AND EFFECTIVENESS OF GRANITE ROCK OUTCROP POOL ENHANCEMENT EFFORTS BY THE U.S. FISH AND WILDLIFE SERVICE (Version 2)

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Table of Contents

Purpose of Report and Efforts	3
Summary of Initial Efforts	7
Rock Chapel Road, DeKalb County	13
Stone Mountain, DeKalb County	15
Arabia Mountain, DeKalb County	20
Greensboro South, Greene County	28
Heggie's Rock, Columbia County	33
Current Status and Assessment of Efforts	40
Stone Mountain, DeKalb County	42
Arabia Mountain, DeKalb County	59
Greensboro South, Greene County	75
Heggie's Rock, Columbia County	84
Final Conclusions and Recommendations	92
References	93

Purpose of Report and Efforts

This report reviews the many granite outcrop pool habitat enhancement efforts by the United States Fish and Wildlife Service (USFWS) and its many partners for the conservation of the endangered species *Isoetes tegetiformans* and *Isoetes melanospora*, and the threatened *Gratiola amphiantha* [syn: *Amphianthus pusillus*]. This report has been prepared by Anna Wyngaarden (UGA) under the guidance of Dr. Mincy Moffett (USFWS) and Dr. Megan DeMarche (UGA). This report is informed by previous reports on the individual projects, as well as interviews and correspondence with those involved in the projects, including Robby Astrove, Jennifer Ceska, Kyla Cheynet, Malcolm Hodges, Pete Pattavina, Jimmy Rickard, Eric VanDeGenachte, and Larry Winslett. Each extant project was surveyed, and all enhanced pools were mapped as geo-referenced polygons in the field, using high-precision GPS equipment. These maps will be shared as shapefiles accompanying this report. The naming convention of each pool used in this report corresponds to how individual polygons are named on the map and remain consistent with historical naming unless otherwise noted. Aerial drone photographs were also taken of each extant enhanced pool, except for at Stone Mountain where conditions were too windy for drone flight and at Rock Chapel Road which no longer exists. The information reported for each project comes from communication with project partners, historical reports and information on the project, or in-field observation by the author. All photographs were taken by Wyngaarden unless otherwise noted.



Granite outcrops are exposed granitic habitats found in the piedmont region of the Southeastern United States, ranging from eastern Alabama through Georgia, South Carolina, and portions of Tennessee, ending in parts of North Carolina. Typically surrounded by mesophytic forest these insular ecosystems are naturally isolated from one another and experience starkly different environmental conditions from the surrounding forest. They support a suite of endemic species, some of the most notable inhabiting their “pool” depressions in the rock formed by natural erosion. These pools are shallow (0.5-3 inches deep) and flat-bottomed and ephemerally fill with water in the winter and early spring months from rainfall and seepage from surrounding habitats. They accumulate veneers of soil that range in depth up to a few inches deep. This habitat supports helophytic aquatic and terrestrial plants, specifically the federally endangered and threatened species, *Isoetes melanospora* Engelm., black-spored quillwort, *Isoetes tegetiformans* Rury, mat-forming quillwort, and *Gratiola amphiantha* D. Estes & R.L. Small,

snorkelwort or pool-sprite. During the summer and fall these pools are usually completely dry. *Isoetes melanospora* and *tegetiformans* require pools with at least 1-2 inches of soil, and the ability to hold enough water for them to be submerged when the pool is filled (1-2 inches of water). This requires pools to be sufficiently deep and able to retain water for a time period sufficient for the species to support their life history requirements.

Isoetes melanospora is a perennial herb with leaves between 1-3 inches tall. A lycophyte, black-spore quillwort reproduces by spores. During dry periods, leaves dry while the corms persist, reproducing leaves shortly after receiving adequate water. Spores are produced in late spring/ early summer and are released when the plants dry out through the summer. Spores are dispersed mainly through gravity, water flow, or insects. *Isoetes melanospora* is endemic to granite outcrops of central and western Georgia (Fig. 1). This species was listed as endangered on the Endangered Species Act in 1988.

Isoetes tegetiformans is a perennial herb that forms dense mats, spreading through rhizomes. Its rhizomes form hummocks, resembling a brain-like formation, a distinguishing characteristic of the species. This species is said to be the most distinguished *Isoetes* in North America because of this characteristic. Its leaves are usually less than 1.2 inches tall and dry up during the dry season. This species primarily reproduces through rhizome but also reproduces by spores. *Isoetes tegetiformans* is endemic to granite outcrops of central and eastern Georgia (Fig. 1). This species was listed as endangered on the Endangered Species Act in 1988.

Gratiola amphiantha is a small, short-lived, aquatic annual with short, linear leaves forming its rooted rosette that remain submerged in water-filled pools. Threadlike scapes are produced from the base, bearing two bracts, or “twinleaves”, that float on the surface of the water. A single small white to pink flower is borne on the scape and is chasmogamous. An additional flower is borne on the base of the plant and when submerged remains cleistogamous, but when the pools dry and the flower is exposed, it will open and become chasmogamous. This species reproduces through seed which is dispersed by gravity, water flow, or animals/insects (suspected on the feet of vultures or other birds). *Gratiola amphiantha* is endemic to granite outcrops from eastern Alabama, through Georgia, and into northern South Carolina (Fig. 1). This species was listed as threatened on the Endangered Species Act in 1988.

The principal anthropomorphic threats to the habitat at large are quarrying, development, trash dumping, off-road-vehicle use, horseback riding, cattle trampling, development of woodlands surrounding granite outcrops, invasive plant species (on the rock and in the pools), and succession of outcrops (hastened by fire suppression and presence of woody invasive species in the surrounding ecotone). Climate change is increasing both heat and drought stress on the rock and in the pools, as well as contributing to larger and more powerful precipitation events which can scour suitable pools of soil and plants. Historically, the most recorded extirpations of the species have come from quarrying and urban development where the outcrop is fully destroyed.

A natural limiting factor of the habitat, and the species’ persistence, is the availability of “quality” pools capable of holding water for a period sufficient for the species to complete their annual life cycles. Many potential pools are too shallow, have a fatal crack in the substrate, have one edge or lip that is too low or compromised in some manner, are in a high flow drainage area that leads to scouring during rain events, have a soil depth that is insufficient or excessive, or are overgrown with competing vegetation. Pools naturally accumulate soil over time, leading to greater soil depths and successional plant growth. *Gratiola amphiantha* can withstand more shallow pool conditions whereas both *Isoetes* species require a deeper soil and pool depth. This

difference in required habitat quality between the species likely plays a large role in determining why *G. amphiantha* is consistently present in more pools compared to either species of *Isoetes*. Pool quality tolerance is reflected in threat and abundance measures impacting federal regulatory status (i.e., endangered vs. threatened). Within the sparse outcrop system, *G. amphiantha* is frequently abundant while both *Isoetes* species remain more restricted in range and abundance.

The U.S. Fish & Wildlife Service (USFWS) has worked with the Atlanta Botanical Garden (ABG), The Nature Conservancy (TNC), Davidson-Arabia Mountain Nature Preserve (DAMNP), and the Stone Mountain Memorial Association (SMMA), to establish additional pools supporting the endangered *I. melanospora* and *I. tegetiformans* by enhancing existing pool habitat or creating new pools for introducing the species. Most projects occurred over a decade ago and their success has not been formally evaluated. The efforts recounted in this report were conducted at five sites: Rock Chapel Road, Stone Mountain Memorial Park, and Davidson - Arabia Mountain Nature Preserve in DeKalb county; Greensboro South in Greene county; and Heggie's Rock in Columbia county (Table 1).

The threatened *G. amphiantha* shares habitat with these *Isoetes* species and has benefitted from these efforts as well. In general, the efforts reported here have been a huge success with most of the established populations still persisting a decade later. A total of 21 new pools supporting *Isoetes* have been established through these efforts, of which 12 are *I. melanospora* and nine (9) are *I. tegetiformans* (Table 2; Table 4). Additional natural pools have been enhanced (managed) by weeding activities. These efforts have been informed and inspired by a handful of trail-blazing individuals and reflect a successful conservation story of multi-institutional collaboration and creativity. The goal of the pool enhancement was to create pools with earlier successional growth to replace those pools with successive plant growth that are phasing out.

This report first summarizes the many efforts and methods used towards the conservation of the pool species, highlighting the influence that each project had on the development of subsequent projects. This report then includes updated evaluations of each pool from surveys in 2022 and 2023 to assess the persistence of these projects since creation. The five sites featured in this report are hereafter referred to as Rock Chapel Road (RC), Stone Mountain (SM), Arabia Mountain (AM), Greensboro South (GS), and Heggie's Rock (HR) (Fig. 1). The timelines of many of these projects overlaps with others, demonstrating the influence of various projects on one another (Fig. 2).

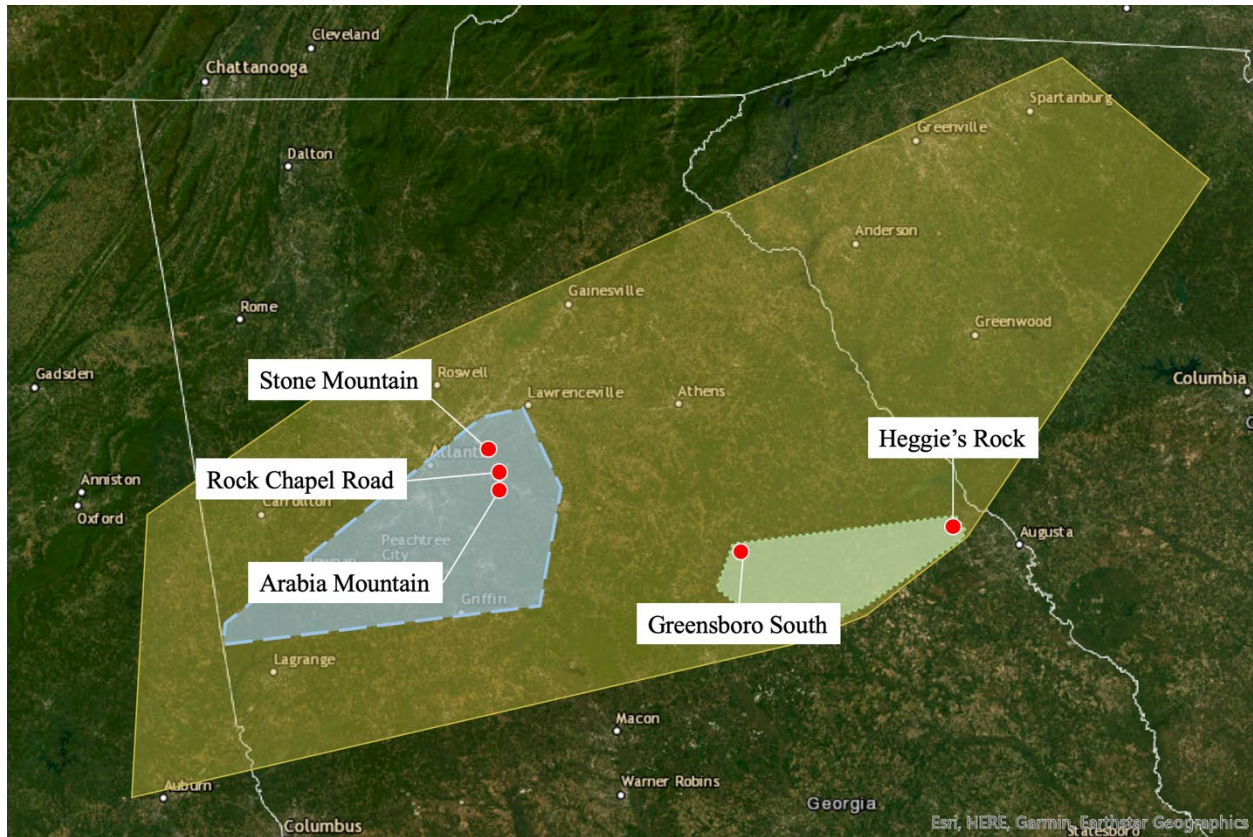


Figure 1. Map showing the location of each project site within each species' geographic range. Polygons reflect the geographic range of each species based on their known occurrences. *Isoetes melanospora*'s range (light blue, dashed edge) is restricted to the western half of Georgia, *Isoetes tegetiformans*' range (light green, dotted edge) is restricted to the eastern half of Georgia, and *Gratiola amphiantha*'s range (yellow, line edge) spans from the Piedmont of eastern Alabama to northern South Carolina.

Table 1. Table showing the county, latitude, and longitude of each site. Coordinates are the general center of the outcrop. Coordinates of individual pools are in Table 3.

Site Name	County	Latitude	Longitude
Rock Chapel Road	DeKalb	33.7	-84.1
Stone Mountain	DeKalb	33.8	-84.1
Arabia Mountain	DeKalb	33.6	-84.1
Greensboro South	Greene	33.4	-83.1
Heggie's Rock	Columbia	33.5	-82.2

Summary of Initial Efforts

“Let’s just make the habitat in a day instead of waiting 10,000s of years.” - Jimmy Rickard

Many creative efforts have been used to enhance the habitat for rare pool species. Lower cost efforts have included weeding competitive material, regularly removing debris, and strategically planting vegetation to buffer the flow of water and sediment into pools. Pools have received transplants of plant material to establish new populations, and existing populations have also been modified. More involved efforts include deepening existing depressions in a variety of methods – manually with steel rods, jackhammers, or diamond blade saws fit onto a skid steer. Other efforts have included the creation of concrete dams to help the pool retain water, a critical element of a suitable pool.

Across all sites, a general framework or protocol has emerged for creating or deepening pools, although minor differences in approaches do exist among the various sites. The first step involves scouting the outcrop and selecting an area where there is a minimal flow of water beyond natural precipitation, and minimal chance for debris accumulation (e.g. ideally not under shedding trees or near public access), this is often at or near the summit of the outcrop where there is minimal slope. Then prospective conservation pools are selected for further investigation. Soils are removed from the existing pool, if necessary, to check for potential leaks (most likely horizontal) and water holding capacity. If existing depressions are deemed suitable for enhancement, they are then deepened using a variety of techniques. The deepened pools are then monitored during the rainy season to assess the pool’s ability to retain water and to determine the presence of major cracks (from the deepening) that could cause leaks in the pool prior to transplantation. During this time, plants are propagated from their natural sources for reintroduction. Once the enhanced pools have been shown to hold water at the proper levels, native soil is reintroduced, sometimes augmented with soil from adjacent pools, and the species of interest are transplanted/outplanted. This has proven overall to be a successful workflow for creating or deepening granite outcrop pools. These efforts have shown that successful pool creation can be completed within 2 to 3 years from pool location selection to establishment of *I. melanospora*, *I. tegetiformans*, and/or *G. amphiantha* populations. Figure 8 shows the ideal pool depths for these two *Isoetes* species when deepening depressions.

Pools have been created de novo from bare rock, or existing depressions deepened. In both instances, jackhammers and diamond blade saws have been used. A key difference between de novo creation and deepening existing depressions is the existing knowledge of the site’s local hydrology. Existing depressions are evidence of the site’s local hydrology and the pool’s ability to hold water. Existing depressions can be monitored for long term water holding capacity before any deepening is done (Stone Mountain, Greensboro South, and Heggie’s Rock). In de novo creation (Stone Mountain, and Arabia Mountain) the hydrology of the site must be inferred with the ability of the created pool to hold water only assessable after creation. This may explain why deepened pools at Greensboro South and Heggie’s Rock have consistently higher percent cover measurements compared to the de novo created pools at Arabia Mountain.

Photos of individual enhanced pools are located in the Current Status and Assessment of Efforts section of this report.

Table 2. Summary of all enhanced pools’ treatment, year of enhancement, source material if applicable, and project partners. (Sites: Greensboro South, Greene County (GS), Heggie’s Rock, Columbia County (HR), Arabia Mountain, Dekalb County (AR), Stone Mountain, Dekalb County (SM).

Species: *Isoetes tegetiformans* Rury (ISTE), *Isoetes melanospora* Engelm. (ISME3), *Gratiola amphiantha* D. Estes & R.L. Small (GRAM3). Abbreviations follow the USDA PLANTS Database symbols.

Treatment: **Concrete** - Concrete lip or “dam” added to help retain water; **Created** - Pool constructed de novo from bare rock;

Deepened - Existing depression deepened using a diamond blade concrete saw and skid steer, with a jackhammer, or hand fractured with metal rod; **Soil Removed** - Soil completely removed from existing pool to add new substrate or wait for recolonization;

Transplanted - *Isoetes* spp. plant material transplanted from existing population into previously unpopulated pool, often grown ex-situ prior transplant. *Gratiola amphiantha* seeds were sometimes transplanted as well from the seed bank in the *Isoetes* soil;

Vegetation Dam – Perennial vegetation planted at water inflow end of pool to buffer the flow of water into the pool; **Weeded** - Pools maintained through weeding competitive *Juncus*, etc.

Organizations Involved: Georgia Department of Natural Resources (GA DNR), United States Fish & Wildlife Service (USFWS), Atlanta Botanical Garden (ABG), The Nature Conservancy (TNC), Plum Creek Timber (PCT), Davidson-Arabia Mountain Natural Heritage Preserve (AR), Stone Mountain Memorial Association (SMMA)).

Success: Shaded boxes continue to support either *Isoetes* species in 2023. Marginal success indicates small populations of either species, likely limited by available soil depth, water holding capacity, or competing vegetation (plant or algae). Substantial success indicates that populations are well established and stable, having grown to fill much of the enhanced habitat since enhancement. Failed success indicates that no plants persist in the pool. All rankings are based on *Isoetes* populations unless otherwise noted.

Site	Pool Code	Treatment	Treatment Year	Plant Material Source	Organizations Involved	Success
RC	RC1	Deepened, Concrete, Transplanted	2004	Rock Chapel Road (extirpated)	GA DNR	Fail and Site Destroyed
HR	Pool #1	Created, Transplanted	2016 created, 2017 transplanted	Mt. Gemini (extirpated)	USFWS, ABG, TNC	Substantial

HR	Pool #2	Created, Transplanted	2016 created, 2017 transplanted	Mt. Gemini (extirpated)	USFWS, ABG, TNC	Fail (Substantial for <i>G. amphiantha</i>)
HR	Pool #3	Created, Transplanted	2016 created, 2017 transplanted	Mt. Gemini (extirpated)	USFWS, ABG, TNC	Substantial
HR	East Pool (K-7)	Transplanted, Concrete	1988 transplanted, concrete, ~2010s concrete repaired	Mt. Gemini (extirpated)	USFWS, ABG, TNC	Substantial (Substantial for <i>G. amphiantha</i>)
HR	West Pool (K-6)	Transplanted, Concrete	1988 transplanted, concrete, ~2010s concrete repaired	Mt. Gemini (extirpated)	USFWS, ABG, TNC	Substantial (Substantial for <i>G. amphiantha</i>)
GS	Pool #1/ Jimmy's Pool	Deepened, Transplanted	2015 created, 2016 transplanted	Greensboro North	USFWS, ABG, PCT	Marginal
GS	Pool #2	Deepened, Transplanted	2015 created, 2016 transplanted	Greensboro North	USFWS, ABG, PCT	Substantial
GS	Pool #3	Deepened, Transplanted	2015 created, 2016 transplanted	Greensboro North	USFWS, ABG, PCT	Substantial
GS	Pool #4	Deepened, (w/rod - inadequate) Added soil, Transplanted	2015 created, 2016 & 2017 transplanted	Greensboro North	USFWS, ABG, PCT	Fail
GS	Pool #5	Deepened (w/rod – inadequate); Not transplanted	2015 created	Greensboro North	USFWS, ABG, PCT	Fail

GS	Kyla's Pool	Deepened, Transplanted	2015 deepened, 2016 transplanted	Greensboro North	USFWS, ABG, PCT	Substantial
GS	Pete's Pool	Soil removed, Transplanted	2016 & 2017 transplanted	Greensboro North	USFWS, ABG, PCT	Marginal
AR	C1	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Substantial
AR	C2	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Substantial
AR	C3	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Substantial
AR	C4	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Marginal
AR	C5	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Substantial
AR	C6	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Substantial
AR	C7	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Substantial
AR	C8	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Substantial
AR	C9	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Marginal
AR	C10	Created, Transplanted	2012 created, 2014 transplanted	Arabia Mountain	USFWS, AR	Marginal
SM	Experiment1	Soil Removed, Vegetation Dam	2016	NA	USFWS, SMMA	Fail
SM	Experiment2	Deepened, Soil Removed	2019	NA	USFWS, SMMA	Fail

SM	Experiment3	ISME3 Transplanted, GRAM3 historic	2014	Stone Mountain (SM1)	USFWS, SMMA	Fail (Substantial for <i>G. amphiantha</i>)
SM	SM1	Source material, Historic ISME3, Weeded	2014, ongoing	Natural Population (Source Material)	USFWS, SMMA	Substantial
SM	SM2	Weeded	2014, ongoing	Natural Population	USFWS, SMMA	Substantial
SM	SM3	Created (jackhammer), Transplanted	2009, 2014	Stone Mountain (SM1 source)	USFWS, SMMA	Fail
SM	SM4	Created, Transplanted, Vegetation Dam	2009, 2014	Stone Mountain (SM1 source)	USFWS, SMMA	Substantial
SM	SM5	Transplanted, Weeded	2014	Stone Mountain (SM1 source)	USFWS, SMMA	Substantial
SM	SM10	Existing Pool; Inoculated from weeded soil from SM2	2015	Stone Mountain (SM1 source)	USFWS, SMMA	Marginal
SM	Pool A	Concrete, Transplanted	2016	Stone Mountain (SM1 source)	USFWS, SMMA	Fail
SM	Pool B	Concrete	2016	NA	USFWS, SMMA	Fail
SM	Pool C	Concrete	2016	NA	USFWS, SMMA	Fail

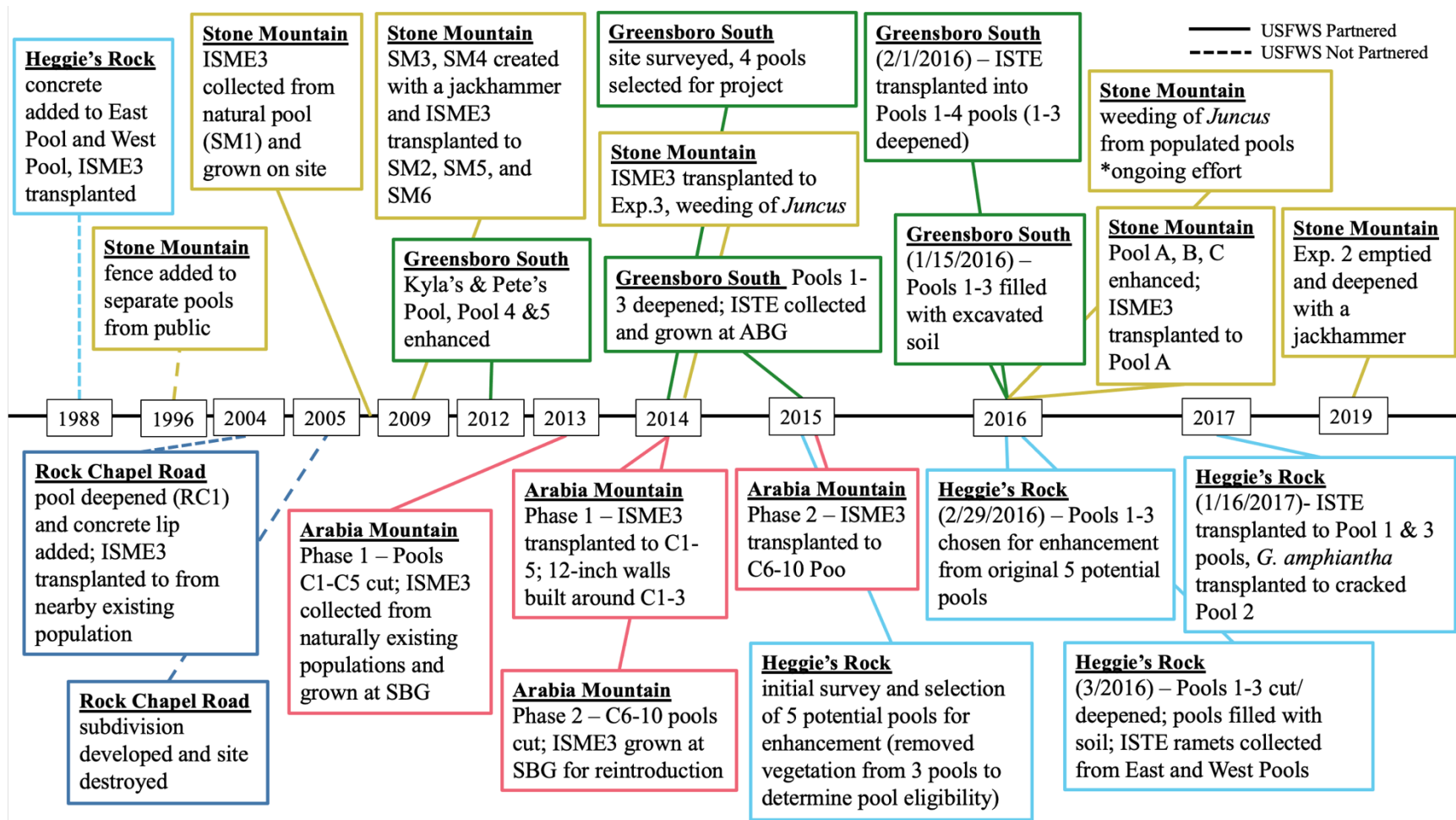


Figure 2. Timeline of enhancement project efforts, color coded by site (Rock Chapel Road, dark blue; Stone Mountain, yellow; Arabia Mountain, pink; Greensboro South, green; Heggie's Rock, light blue). Some efforts at Stone Mountain are ongoing (e.g. weeding of competing material, debris removal) and reports on its efforts are updated regularly.

Rock Chapel Road, DeKalb County

Organization Involved: Georgia Department of Natural Resources (GADNR)

Project Partners: Eric VanDeGenachte

Reporting on this project is based on the memory and records of Eric VanDeGenachte who was a wildlife biologist with GA DNR from the late 1990's to the late 2000's. He was the principal investigator of the efforts at Rock Chapel Road. Many of the records that once existed on the project had been destroyed prior to contacting VanDeGenachte for an interview. Eric no longer resides in the United States, so further communication may prove difficult. No photographs have been found of the project. Below I summarize the information from correspondence with VanDeGenachte regarding the site and enhancement efforts.

Eric VanDeGenachte was one of the first known to implement enhancement efforts for granite outcrop pools and is viewed by many as a pioneer in this field of restoration. VanDeGenachte completed his graduate work at The University of Georgia on the genetics of both *I. tegetiformans* and *I. melanospora* and was well informed with the prehistoric species' habitat. Working for the Georgia Department of Natural Resources under Jon Ambrose, he began work at an outcrop, Rock Chapel Road, in DeKalb County, around 2002. This outcrop was developed into townhomes in 2005 and no longer exists (Fig. 3).

In 2002, a single existing population of *I. melanospora* was found in an "abandoned quarry pool" on the Rock Chapel Road outcrop. VanDeGenachte suspected that the monadnock that once existed across Rogers Lake Road had originally contained more populations of the species but were lost due to quarrying prior to the time of this project. The existing, small population was under threat by competing vegetation and "was likely to die in the next decade." VanDeGenachte proposed transplanting the species to a neighboring pool a couple dozen meters away after "enhancing it", as there it would experience less biotic competition. The landowner wasn't interested in putting the property into a conservation easement and there was little interest in investing in the site from other agencies because of its proximity to development, relatively small size, and quarrying history. After speaking with the landowner and gaining permission to "do whatever [he wanted]", VanDeGenachte began his effort in creating a more enhanced habitat for the existing *I. melanospora* population.

In 2003 or 2004 (VanDeGenachte did not remember the exact year), an existing pool was chosen for enhancement because it was in reasonably good shape with sufficient soil, although one side of the solution pit was broken, allowing for water leakage. The pool was roughly 24 inches in diameter. The pool was deepened using a jackhammer, breaking up the top 1-1.5-inch patina of granite. Using the jackhammer, VanDeGenachte drilled holes in a triangular pattern and smashed the granite which would then "flake off". Once the most weathered, top layer of granite had been removed, the jackhammer reached its limit and was insufficient in deepening the pool further. This was a clear limitation to achieving the desired pool depth. To better retain water and stop its outflow from the pool, concrete was laid along the edges of the enhanced pool to reinforce the rim. Plants and soil from the existing population were then transplanted into the newly enhanced pool.

VanDeGenachte recalls the population initially persisting in the enhanced pool, but ultimately failing, with no evidence of reproduction. It's suspected that, over time, the seal of the concrete addition failed, and the pool began to leak. Unfortunately, a few years after these efforts were completed, the outcrop was sold and developed, erasing any evidence of its success or failure. This effort was a proof of concept that both deepening pools with a jackhammer and

using concrete as a barrier were reasonable approaches for enhancing this habitat, allowing for more refined methods and approaches to be developed in coming projects. Concrete had been used to enhance pools at Heggie's Rock in the 1980s and is discussed below, although VanDeGenachte does not recall hearing about this effort prior to his use of concrete. While not explicitly related to the USFWS projects, VanDeGenachte's efforts were known to the plant conservation community and played a role in conceptually framing the projects to come.

This site is not included in the Current Status and Assessment of Efforts section because it could not be resurveyed.



Figure 3. Rock Chapel Road outcrop satellite image from 2002, 2005, and 2022, showing the destruction of the outcrop for suburban development (Google, 2002; Google, 2005; Google, 2022).

Stone Mountain, DeKalb County

Organizations Involved: SMMA, USFWS

Primary Project Partners: Larry Winslett, Jimmy Rickard

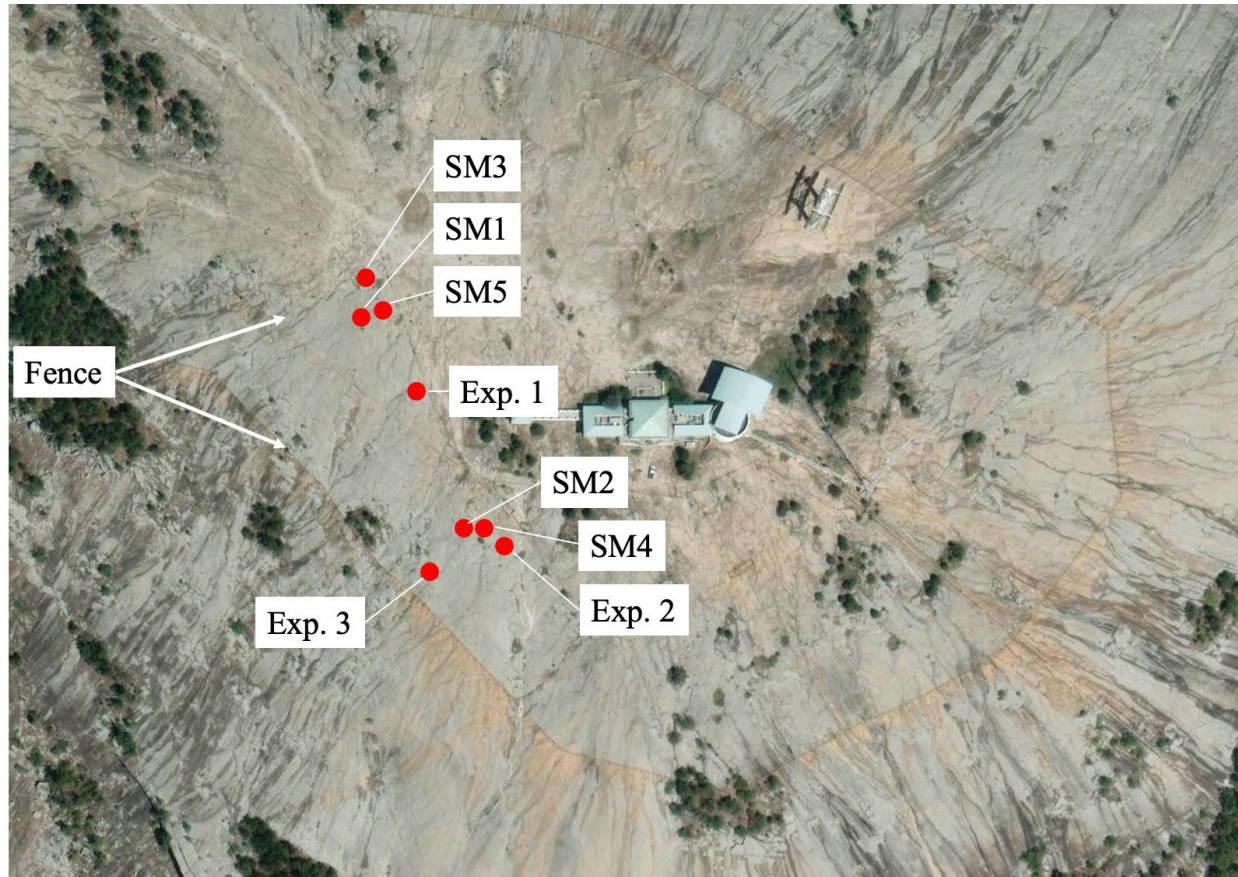


Figure 4. Map of the summit of Stone Mountain, showing the fence built prior to the 1996 Olympics as a faint outline and marked with arrows. Red points correspond to individual pools with their assigned naming designations. Corresponding pool coordinates are available in Table 3 (Google, 2021).

Enhancement efforts at Stone Mountain include the de novo creation of pools, transplanting *I. melanospora* into existing and created pools, weeding of competitive vegetation, strategically planting vegetation to buffer water flow into pools, and using concrete to enhance pool rims. Information reported here is based on interviews and a site visit with Larry Winslett, Land Management Plan Coordinator (SMMA), as well as report prepared for by Winslett in 2014 and updated in 2016 (Winslett, 2016).

Spearheaded by Winslett, in accordance with the federal Endangered Species Act Recovery Plan for *I. melanospora* and guidance from Jimmy Rickard, a Listing and Recovery Biologist with the USFWS, numerous unique and creative efforts for the conservation of the pool species, *I. melanospora* and *G. amphiantha* have been accomplished at this site. Stone Mountain is a highly-trafficked granite monadnock in Stone Mountain, Georgia and is one of the most visited attractions in Georgia. Two natural pools with *I. melanospora* (SM1 and SM2) and an

unknown, but small number of pools with *G. amphiantha*, occurred on the apex of the monadnock (Fig. 4). These were easily trampled by visitors, depleting the habitat and populations.

In anticipation of increased foot traffic with the coming 1996 Olympics in Atlanta, Georgia, a fence was built around a portion of the populated pools, encompassing roughly 8.2 acres of the Stone Mountain summit, south of the observation deck. The construction of the fence was not conducted by the USFWS but was one of the first steps in conserving the rare plant populations at the park.

The restoration efforts at Stone Mountain are managed and documented mainly by Winslett. Prior to conservation efforts, there were two (2) natural populations of *I. melanospora* at the summit of Stone Mountain, pools named here as SM1 and SM2. Habitat restoration approaches at Stone Mountain are the most diverse among all the sites covered in this report. They include planting introductions of *I. melanospora*, weeding of competing *Juncus* spp. and other species, de novo pool creation, deepening of existing pools, planting “vegetation dams” to buffer water flow, and the removal of trash and debris from pools. These efforts are ongoing. Three pools have been created or deepened with a jackhammer. A total of 12 pools have been manipulated in at least one of the ways mentioned above. Ramets of *I. melanospora* from the SM1 population have been propagated for introduction into the enhanced pools recounted below.

Two pools, SM5 and SM10, were existing depressions. Pool SM5 contained *G. amphiantha* and was inoculated with *I. melanospora* in 2014 from propagated material; pool SM10 was inoculated using weeded soil from SM2 in 2015, likely containing propagules of both species.

One (1) of the 12 pools, named Experiment 3 (Exp. 3), had a historical population of *G. amphiantha*, at the time these efforts began in 2009. There are no historical abundance data on *G. amphiantha* populations in any pools within the fenced area, but it is believed that their presence was limited. Winslett attests that he has observed the continued colonization of *G. amphiantha* within the fenced area, believing the movement of seeds by wind or animals to be the primary vector given no visible signs of water flow from populated pools to unpopulated pools. The lack of foot traffic has likely allowed the pools to fill with sediment since the installation of the fence in 1996 and, thus, support new populations of *G. amphiantha*. Existing depressions outside of the fence are subject to frequent foot-traffic and disturbance and, thus, have insufficient amounts of soil, if any, to support these species. The fence that excludes public foot-traffic is the first line of defense for these species.

Winslett has successfully cultivated *I. melanospora* from the two natural populations since approximately 2009. Grown in plastic Tupperware casserole trays, the plants are left to grow on site at the park in an open-air cinderblock HVAC structure (Fig. 6). Winslett supplements water sparingly, noting that it’s important for the plants to dry out throughout the season. They are kept outdoors and are exposed to the same weather patterns as the natural populations at the summit. Plants were originally collected from populated pools. Native soil was collected from both populated and unpopulated neighboring pool in order to obtain the requisite amount. As propagules have continued to grow, they’ve been transplanted into new trays which Winslett has filled with standard potting mix. He claims the plants perform just as well as in native soil. The propagules have grown to cover the entirety of their pans. Additionally, *G. amphiantha* were present in the native soil and this species has grown robustly in the trays as well, despite no direct collecting or transplanting of their seeds. Winslett will routinely remove debris that has fallen into the trays but does minimal additional maintenance.

The low-tech, minimal-effort approach for successful cultivation of these species should be recognized as a powerful tool in the continued conservation of these species. Establishing *ex-situ* populations of these species is a key first step to any reintroduction efforts.

In this report, the pools at Stone Mountain follow the naming convention SM1, SM2, and so forth. These are the field names Winslett originally gave the pools years ago. These names are reflected in this report (surveying, mapping, writing). Some pools are named Experiment 1, 2, etc. These pools have been named this way because they were enhanced at different times from the original naming of SM1, SM2, etc.

There were some discrepancies in the naming conventions between different versions of SMMA reports (Winslett, 2016) and field names developed during the course of this documentation project. All existing reports and mapped pools have photographs of the pool allowing the pool attribute information for each pool to be associated with the correct pool, despite differing names. Pool names in this report reflect field names in use at the time of this project's survey with Winslett. Further, Pool A, B, and C are named differently because they are located in a separate part of the park, did not have successful conservation outcomes, and are considered problematic candidates for future conservation efforts because of their location to human impacts.

SM1 (Pool #1 in SMMA reports) and SM2 (Pool #5 in SMMA reports) are historic populations of *I. melanospora* and are routinely monitored for *Juncus* encroachment and removal. Some of the *Juncus* plants removed from these pools have been transplanted into other pools at the point of surface water inflow to act as a vegetation dam. This slows the speed at which water flows into pools reducing the chance of plants becoming uprooted and washed out with heavy rains. SM3 (Pool #3 in SMMA reports) had *I. melanospora* transplanted into it, and competing grasses are occasionally removed from the pool. Experiment 1 has had *Juncus* and grasses transplanted as a vegetation dam for the inflow of water and is being monitored as a potential pool for future deepening and/or *I. melanospora* transplanting based on its depth and water retention. Experiment 3 had an existing *G. amphiantha* population and *I. melanospora* was transplanted into the pool in 2012. The success of each pool is discussed below.

In 2009, two (2) pools, SM3 and SM4, were created de novo from bare rock using a jackhammer. Pool locations were chosen based on their location at the summit of the mountain, within the fenced area, and close to the natural populations. Similarly, to Rock Chapel Road, the jackhammer was only able to remove the upper layers of the granite, limiting how deep the pools could be made. Shortly after deepening, *I. melanospora* was transplanted from the propagated trays.

In 2019, a third pool, Experiment 2, was deepened with a jackhammer. It was an existing depression that had been monitored and was chosen to be deepened based on its water retention and accessibility. This pool had been considered for two treatments, either deepening with a jackhammer, or damming the outflow side of the pool by planting *Juncus* spp. Prior to deepening, Experiment 2 supported *Diamorpha smallii*. *Juncus* was planted at the inflow of water, to buffer the momentum of the flow and encourage plant retention. No *I. melanospora* has yet been transplanted into Experiment 2.

In a separate part of the park, within a remnant outcrop nestled within a parking lot near the ground-level entrance to the cable car, three pools have been enhanced (Fig. 5; Fig. 27). In 2019, concrete lips were added to Pools A, B, and C to help retain water. *Isoetes melanospora* was transplanted into Pool A using plants from the propagation trays. By 2022, no *I. melanospora* was surviving in the pool, and none of the concrete dams/lips were present. It's

suspected that the high volume of foot traffic through the outcrop led to the demise of the transplant and concrete. Winslett said that the concrete was missing due to “vandalism”. The remnant outcrop is surrounded by parking lot or road and is adjacent to the Memorial Hall, receiving constant traffic from visitors. When not in the growing season, pools with pristine habitat for *I. melanospora*, *I. tegetiformans*, and *G. amphiantha* are barren and dry, resembling little more than a pit of sand and soil. To an unknowing visitor, these out-of-season pools do not appear special and are frequently walked through or played in.

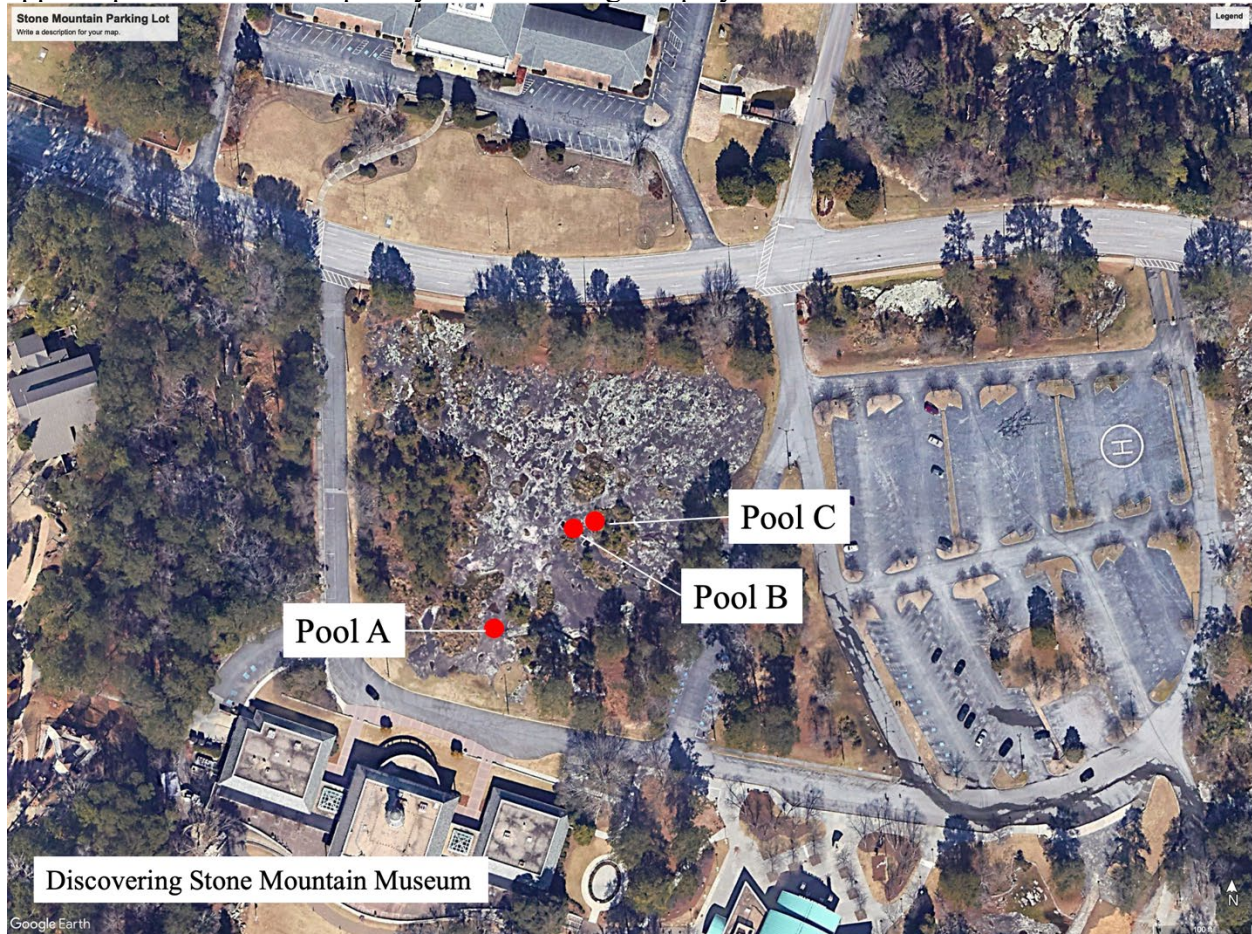


Figure 5. Map of the parking lot at Stone Mountain where additional enhancements were completed but no longer support any species. Red points correspond to enhanced pools A, B, and C (Google, 2021).



Figure 6. Plastic Tupperware trays with populations of *I. melanospora* and *G. amphiantha* from the summit of Stone Mountain. Trays are monitored with minimal interference or supplemental watering. This method of propagating *I. melanospora* and *G. amphiantha* was successfully devised by Larry Winslett and has become the standard practice for cultivating the species for conservation, cultivation, and research purposes.

Arabia Mountain, DeKalb County

Organizations Involved: USFWS, Davidson-Arabia Mountain Nature Preserve

Primary Project Partners: Debbie Harris (USFWS), Jimmy Rickard (USFWS), Charlie Monroe (DeKalb County)

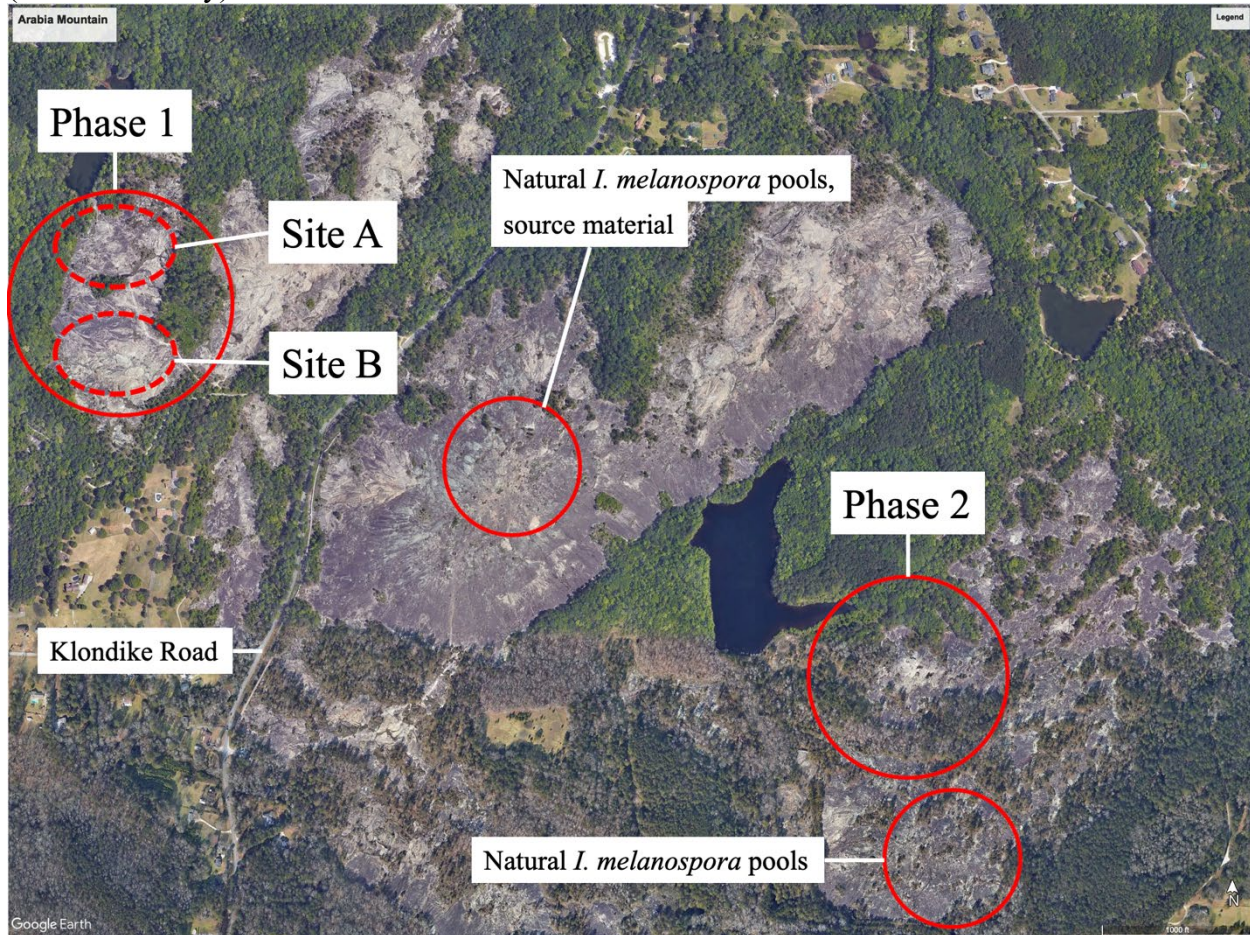


Figure 7. Map of Davidson-Arabia Natural Heritage Park showing locations of Arabia Mountain enhancement project sites in red circles. Phase 1 is on the western side of Klondike Road, containing both Site A and Site B. Phase 2 is located on the eastern side of Klondike Road. Phase 1 has five (5) enhanced pools and Phase 2 has five (5) enhanced pools. Locations of natural pools supporting *I. melanospora* within the park are shown (Google, 2022).

Enhancement efforts at Arabia Mountain began in 2014 and include the de novo creation of pools from bare rock, transplanting rare species into created pools, propagating rare species, and weeding of competitive vegetation. De novo creation involved the cutting of completely new pools out of existing flat rock where no depression naturally existed. A total of ten pools have been created at Arabia Mountain, in two separate parts of the park (Phases 1 and 2; Fig. 7). The enhancement projects at Arabia Mountain have inspired and facilitated several educational outreach opportunities, including hikes, educational programs, and interpretive signage to serve the public, to promote conservation, to further strengthen community buy-in to the project. Arabia Mountain is home to the largest number of naturally populated pools of both *G. amphiantha* and *I. melanospora* throughout either species' range. Information reported here is

based on interviews with Jimmy Rickard, Robby Astrove, and Jennifer Ceska, as well as project reports prepared by annually Charlie Monroe from 2013-2016.

The project at Arabia Mountain was funded by the USFWS's Partners for Fish and Wildlife Program which provides technical and financial assistance to private landowners wishing to improve habitat on their land, including benefitting federally listed and at-risk species. At that time, Debbie Harris was the Partners of Fish and Wildlife Biologist (USFWS). Two (2) sites received enhancements at the Davidson-Arabia Mountain Nature Preserve and are referred to as Phase 1 and Phase 2.

In 2012, five pools (C1 - C5) were created on the western side of Klondike Road (Phase 1), and five pools (C6 - C10) were created on the eastern side of Klondike Road, east of Mountain Lake (Phase 2). The areas of the park selected for pool creation had undergone quarrying in the past and, thus, had no existing natural depressions or pools. They were also located away from the main trafficked paths of the park. There are existing natural populations of *I. melanospora* and *G. amphiantha* at Davidson-Arabia Mountain Nature Preserve (Arabia has the largest known population of the species, as well as the greatest number of populated pools at a single site) in two locations within the park. Both locations with naturally occurring populations are located on a separate peak, away from the created/enhanced pools.

Having witnessed the limitations of using a jackhammer to deepen pools at Stone Mountain, Rickard collaborated with concrete contractors who cut and removed hardened concrete to develop an approach to more effectively cut granite rock. They suggested crosscutting the granite with a diamond blade concrete saw and removing the individual crosscut pieces. DeKalb County government contracted with the Environmental Consortium, LLC to excavate the pools. This method was successful at deepening the pools to 4 inches and was first implemented in Phase 1 at Arabia. This method would be used in Phase 2 at Arabia, as well as at Greensboro South and Heggie's Rock. Prior to pool creation at Arabia, *I. melanospora* plants were collected from existing, natural populations in the park located on the top of Mount Arabia, "the mother pools" as referred to by Robby Astrove, the Park Ranger at Arabia Mountain. The plants were increased at the State Botanical Garden for a year and eventually transplanted into the newly created pools.

Arabia Mountain is the most publicly visited location of all the pool enhancement projects across the state and all enhanced pools are accessible to the public. Since their creation, the enhanced pools at Arabia have been used for educational purposes, informing the public about efforts to enhance habitat for rare plant species. Some educational programs have included organized regular volunteer efforts to remove debris from the pools, Ranger-led hikes to the pools, and educational fieldtrips for local elementary and middle schools. Three of the ten total pools are explicitly highlighted or shown on Ranger-led tours, but all pools are accessible to the public. Arabia Mountain has set an example of sharing conservation efforts with the public through guided tours, educational brochures, and constructing display stands. As the home to the largest populations of two federally endangered species, Arabia Mountain does an exceptional job of informing the public of the presence of rare species in a manner that protects the integrity of both the natural and enhanced populations.

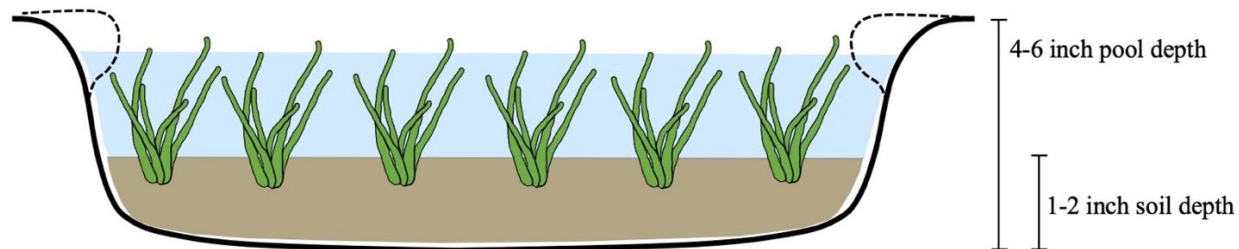


Figure 8. A cross-section of an idealized pool created de novo from bare rock to support either *Isoetes* species. Pools will have a depth of four to six inches and containing one to two inches of soil. Standing water levels will fluctuate but may reach one to two inches when full. Pools have level, flat bottoms with no cracks or leaks. Pools may have a defined edge or lip (dotted lines), increasing the pool's ability to hold water. This is the general engineering design used for all pool creations at Arabia Mountain, Greensboro South, and Heggie's Rock.

Phase 1: In 2013, five (5) pools were created during Phase 1 on the western side of Klondike Road, using concrete saws, to create new habitat for *I. melanospora*. Two (2) locations were selected for Phase 1, Site A and Site B. Site A is located in a highly visible part of the park, near one of the main park trails from the Nature Center. Site B is more secluded and receives less foot-traffic. Three (3) pools were created at Site A and two (2) pools were created at Site B. Pools at Site A were cut in bare rock that had previously been quarried (Fig. 9) and the pools at Site B were cut into existing depressions along the edge of the outcrop (Fig. 10; Fig. 12). Each of the pools were cut using concrete saws to roughly 4ft x 4ft in area and 4 to 6 inches deep, depending on how deep the saw could cut. Once cut, the pools were monitored monthly to assess their water holding capacity and check for leaks to determine success prior to transplanting any species. This depth of pool was chosen to ensure an adequate depth to support *I. melanospora* but not deep enough to encourage competitive herbs and graminoid species (Fig. 8). This depth allows for enough soil (1-2 inches) to support the species, as well as for the pool to hold 1-2 inches of water when saturated.

This same year, 2013, 1ft² samples of *I. melanospora* were collected from the natural populations at Arabia Mountain and were increased at the State Botanical Gardens to be later transplanted into the created pools. Seeds of *G. amphiantha* were present in the collected samples and germinated in cultivation, although they were not intentionally collected. *Isoetes melanospora* was successfully grown out and, in 2014, was transplanted into the enhanced pools. Using the excavated granite from the pool deepening plus concrete, in 2014 walls were built around the three pools in Site A to delineate the pools to visitors (Fig. 13). The walls resembled that of a stone wall around an old well. When monitored in 2022, little of the walls remain intact, the granite pieces were strewn around the cut pools suggesting concrete failure, human disturbance, or both.

Phase 2: Pool creation in Phase 2 mirrored that of Phase 1. In 2014, an additional five (5) pools were created in Phase 2, in a separate portion of the park, east of Mountain Lake (Fig. 11). This portion of the park was newly acquired at the time. Similarly, to Phase 1, this portion of outcrop had been quarried and no natural depressions remained, making it ideal for pool creation. It is also a remote portion of the park that receives remarkably less traffic than other parts of the park. Located at the top of the outcrop, these pools receive direct rainwater with minimal run-off and leaf litter input.

These pools were also created with concrete saws, cutting the rock in a crosscut fashion and the chunks of granite were then removed. The pools were cut to roughly 4ft x 4ft and 4 to 6 inches deep to hold 1-2 inches of soil and 2-3 inches of water above the soil line when fully saturated. Pools were monitored for water holding capacity over the next year to determine the presence of leaks. More *I. melanospora* was grown at the State Botanical Gardens for reintroduction to the Phase 2 pools in the same manner it had been grown in Phase 1. In 2015, the Phase 2 pools were deemed successful and *I. melanospora* was transplanted.

Since creation, pools have been monitored with some regularity. In 2015 and 2017, the percent coverage of both *I. melanospora* and *G. amphiantha* were recorded for each of the 10 enhanced pools by project partners. Pools have been weeded of competing material throughout the years, offering an educational activity the park would use to engage visitors and students. Two of the pools in Phase 2 (C7 and C10) were created with an unlevel bottom – the result of topography and cutting logistics. This has resulted in the *I. melanospora* favoring the deeper sides of the pools. This is explained further in the Current Status and Assessment of Efforts section of this report.

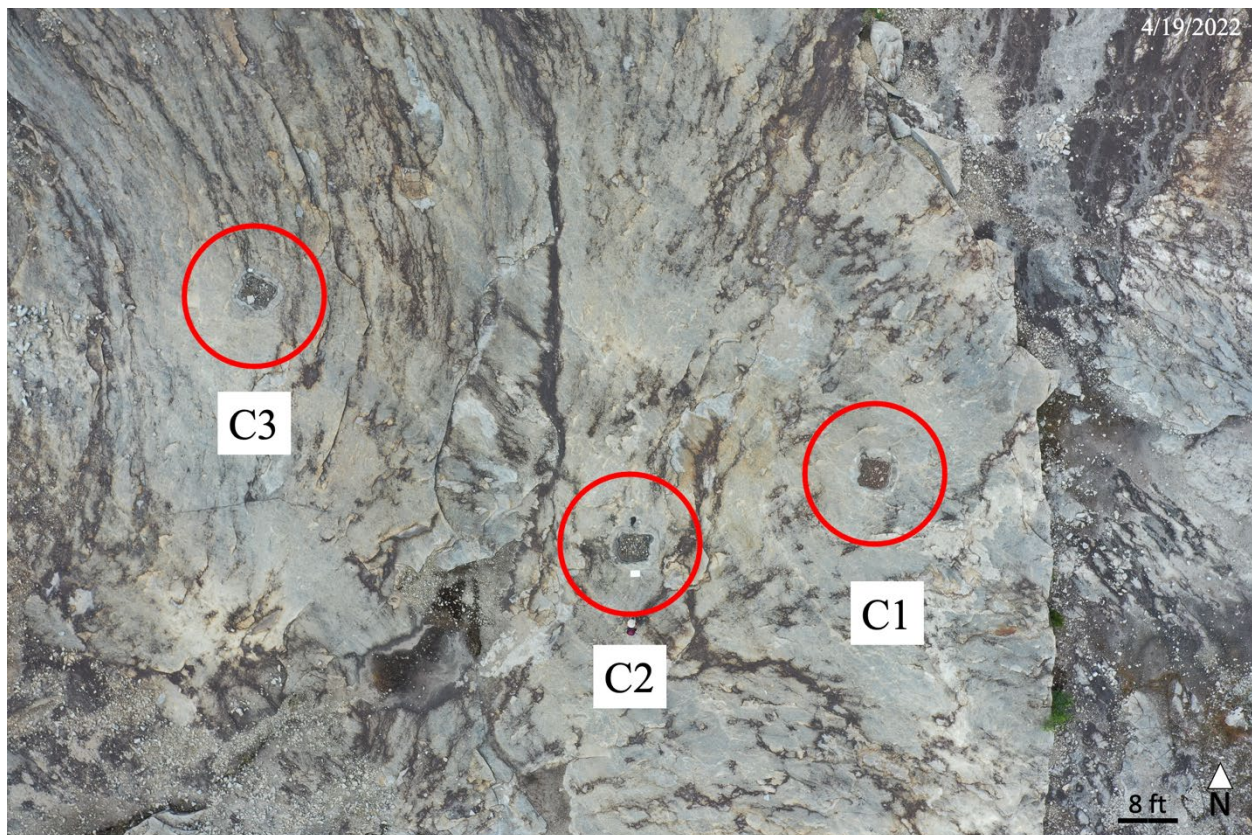


Figure 9. Site A of Phase 1, with circled enhanced pools C1, C2, and C3. Corresponding pool coordinates are available in Table 3. This image was taken by DJI Mavic Pro drone on 4/19/2022.

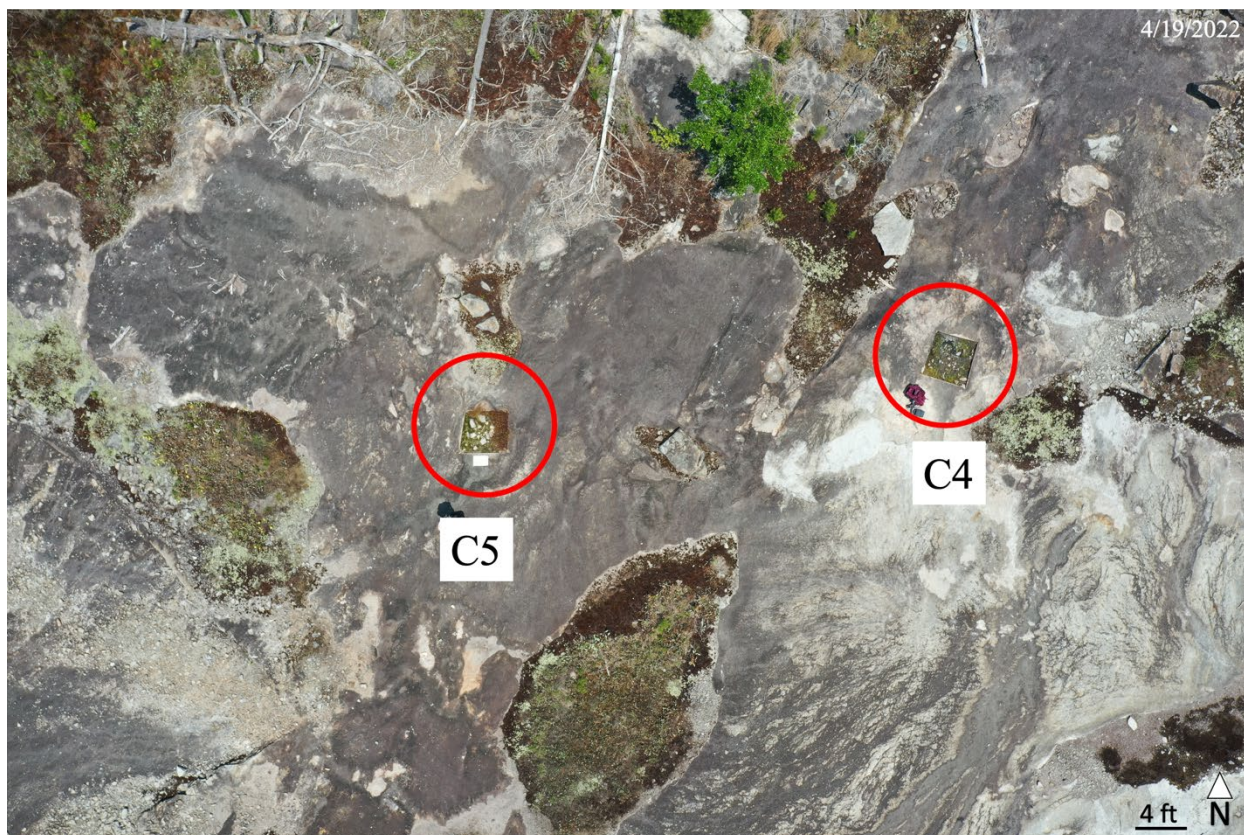


Figure 10. Site B of Phase 1, with circled enhanced pools C4 and C5. Corresponding pool coordinates are available in Table 3. This image was taken by a DJI Mavic Pro drone on 4/19/2022.

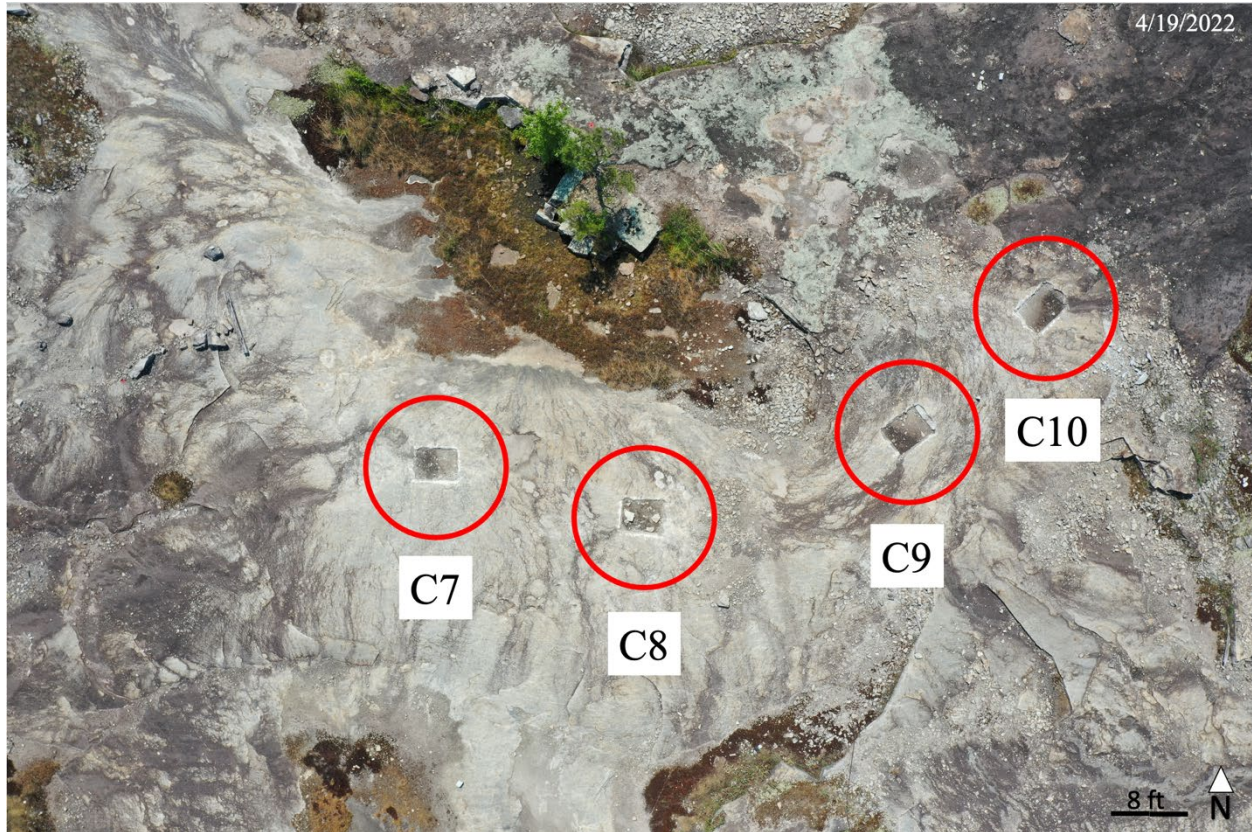


Figure 11. Phase 2 with circled enhanced pools C7, C8, C9, and C10. C6 is located just outside of the photo in the bottom left corner. Corresponding pool coordinates are available in Table 3. This image was taken by DJI Mavic Pro drone on 4/19/2022.



Figure 12. Looking west at Phase 2 of Arabia Mountain where C6-C10 are in a remote part of the park that was once quarried. Few natural depressions exist in this portion of the outcrop and the enhanced pools were in the center of the outcrop, away from the surrounding forest edge.



Figure 13. Walls constructed around pools in Site A of Phase 1 at Arabia Mountain. These walls have been dismantled and no longer stand (Richards, 2015).

Greensboro South, Greene County

Organizations Involved: Atlanta Botanical Garden, State Botanical Garden of Georgia, USFWS, Plum Creek Timber, Penhall Contractors

Primary Project Partners: Jimmy Rickard (USFWS), Kyla Cheynet (Plum Creek), Debbie Harris (USFWS), Jennifer Cruse-Sanders (ABG), Matt Richards (ABG), Pete Pattavina (GA DNR)

Enhancement efforts at Greensboro South consisted of two (2) separate projects, each with separate funding (Fig. 14). The first project was initiated with Drew Marczak, the Wildlife Biologist at Plum Creek Timber by Rickard (USFWS) in 2012. The second project was started in 2014 and involved the Atlanta Botanical Garden (ABG) and was funded under the same grant that supported the efforts at Heggie's Rock. Information reported here is based on site visits with Rickard and Pete Pattavina (Consultation Biologist with the USFWS), project reports prepared by Matt Richards (Conservation Horticulturalist with ABG) in 2015 and 2016, and interviews with Rickard and Kyla Cheynet, the succeeding Wildlife Biologist for Plum Creek Timber at the time of the project.

Marczak retired at the beginning of the first project, and his role was assumed by Cheynet. Kyla's Pool, Pete's Pool, and Pools 4 & 5 were enhanced in this first effort (Figure 14). In January 2012, *I. tegetiformans* was collected from a natural population on an adjacent outcrop, Greensboro North (Veazey), owned by Plum Creek (Fig. 15). Plants were increased at the State Botanical Garden of Georgia for one year. In December of 2012, the soil in both Kyla's pool and Pete's pool was removed for deepening and various methods were tried to deepen the depression. Pool 4 and Pool 5 had less than an inch of soil to remove and replace.

An initial attempt with a steel rod and hammer was used to manually fracture the granite but was only able to remove the thin, weathered top layer. A jackhammer was then used to deepen the pool, also proving unsuccessful at reaching the desired 4-inch depth. Ultimately, a diamond blade saw on the front of a skid steer was used to cut Kyla's pool (Fig. 23). A local independent contractor, often employed by Plum Creek, was hired to run the machinery. As Cheynet recalled, "I had no idea how hard granite was until that day".

Large machinery could easily access Kyla's pool enabling the use of the diamond blade saw. Pete's Pool, Pool 4, and Pool 5 were not easily accessible by a skid steer and only received manual fracturing. The steel rod removed the top patina of the granite but was not successful in substantial deepening. No species were transplanted into Pools 4 or 5, but minor evidence of the manual fracturing is still present.

Before *I. tegetiformans* was transplanted into Kyla's pool (also called "Isoetes pool" in some USFWS reports) soil was collected from surrounding, unpopulated pools to obtain enough soil volume to fill Kyla's pool before transplanting. The collected soil was placed into a metal barrel which was then heated on a portable barbecue grill to sterilize the soil and kill any potential competing vegetation present in the soil seed bank. It's unclear if this successful or useful. In January of 2013, the propagated *I. tegetiformans* was transplanted into Kyla's pool and has since established well. Small amounts of *I. tegetiformans* was transplanted into Pete's pool but it did not persist into the following year.

The second enhancement project at Greensboro South began in 2014 around the same time as the Arabia Mountain projects. This project included the deepening of three existing depressions following the same skid steer and diamond blade saw method that proved successful for Kyla's pool (Fig. 23). This project was funded under the same grant as the efforts at Heggie's Rock. These efforts included deepening existing pools and growing and transplanting *I.*

tegetiformans. These efforts were completed as a joint project with the USFWS, ABG, and Plum Creek Timber, who owned the property at the time of the project. Weyerhaeuser now owns the property. The second project occurred south of the first efforts on the same outcrop.

In June of 2014, Greensboro South was initially surveyed, and four (4) pools were selected for cutting and deepening, based on their location at the top of the outcrop for drainage purposes, their current depth, ability to hold water, and accessibility by cutting machinery. In February of 2015, outcrops north of Greensboro South were visited, where natural, robust populations of *I. tegetiformans* exist. Ramets of the species were collected and transplanted into flats with native soil at ABG. These ramets were increased at ABG for later reintroduction into the created pools at Greensboro South. This method of propagation mirrors Winslett's methods at Stone Mountain (Fig. 6).

In February 2015, Penhall contractors and project partners assembled at the Greensboro South granite outcrop to begin pool deepening. Water was pumped out of the existing pools, and existing native soil was removed from all pools prior to cutting (Fig. 16). Removed soil would be used, along with soil from neighboring pools, to refill the deepened pools later, after "sterilizing" in metal trashcans using a flame weedkiller. Plywood was laid along the rim of the pools prior to cutting to minimize damage from equipment. A diamond blade concrete saw was used to cut a cross hatch pattern into the pool at a depth of 4 inches, the maximum depth the blade would reach. A square of roughly 1 meter x 1 meter was cut in this crosshatch pattern, following the methods used at Arabia Mountain (Fig. 17). This loosened the granite, and the remaining large chunks were demolished using a skid steer with a jackhammer attachment. The demolished granite was removed by hand. The jackhammer was used to smooth the edges of the created pools. Three (3) of the four (4) pools were successfully deepened, with Pool 3 posing some challenges as it was not as easily accessible by the mechanized equipment. Pool 4, while a good candidate for enhancement, was not cut because of time constraints that day.

In March 2015, the deepened pools were assessed for their water holding capacity during the spring rainy season. All three of the deepened pools retained an appropriate depth of water and were deemed ready to be filled with native soil (original removed soil and borrowed soil from surrounding pools) to a depth of two (2) inches. At the time of assessment, all pools held 3-4" of water above the soil line. This assessment of the pools confirmed that they held water well enough to receive *I. tegetiformans* transplants.

In February 2016, the *I. tegetiformans* collections being grown at ABG had increased to cover 90% of a standard 3" x 10" x 20" nursery flat. This tray of *I. tegetiformans* was used to populate the three enhanced pools. Small divisions of the species were separated and transplanted into the enhanced pools (Pools 1-3). In Pool 1, approximately half of the tray was planted; Pool 2 received approximately ¼ of the tray, and Pool 3 received the final ¼ of the tray. Pool 4, which was manually fractured in the first enhancement effort received roughly 40 ramets after assessing the pool's water and soil levels.

In January 2017, additional *I. tegetiformans* propagules were transplanted into Pete's Pool and again into Pool 4; the roughly 40 ramets transplanted to Pool 4 in 2016 did not survive. *I. tegetiformans* persists in Pete's Pool as of 2023, as shown in the summary section below.

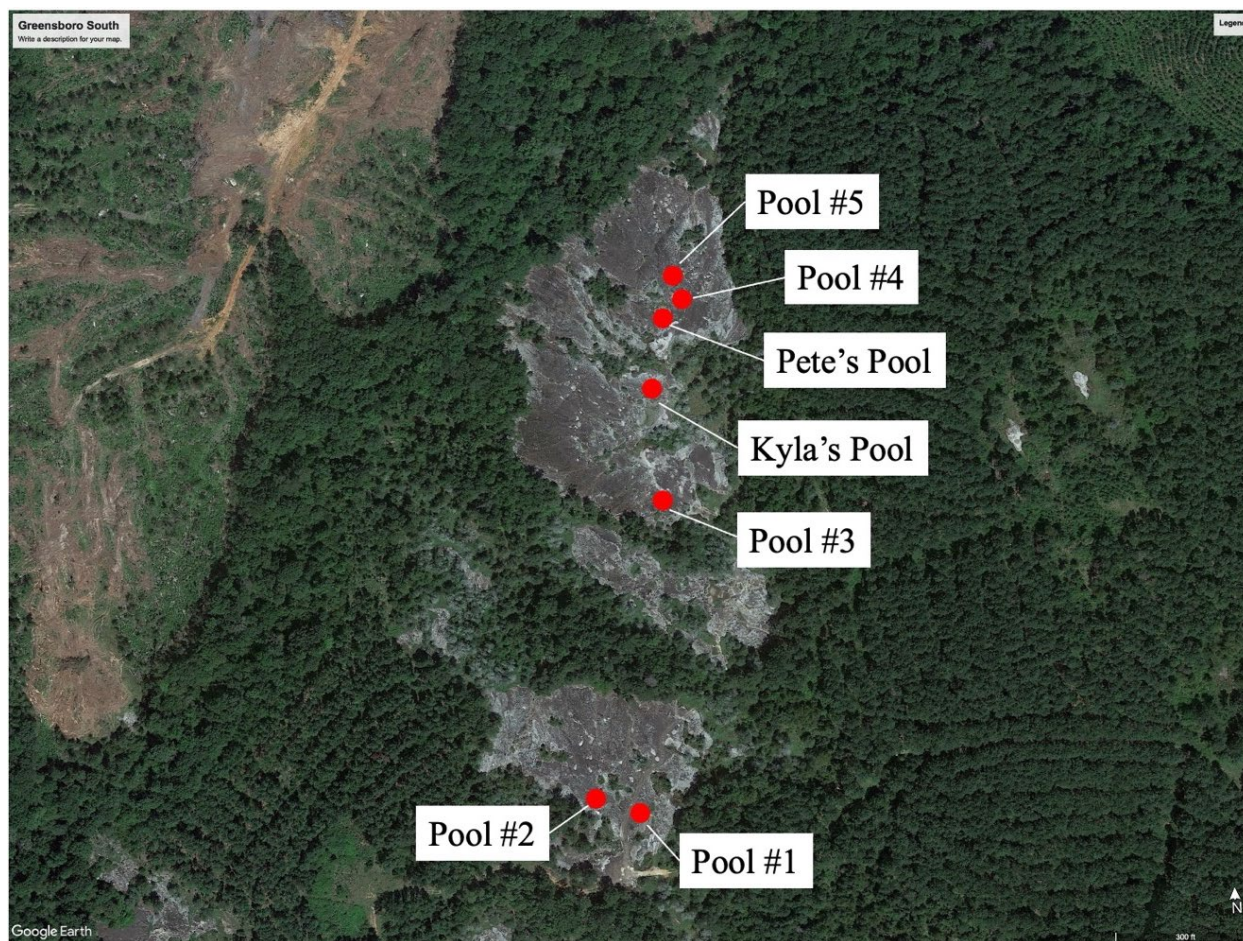


Figure 14. Map of Greensboro South with enhanced pools marked as red waypoints. Corresponding coordinates are available in Table 3 (Google, 2021).



Figure 15. Map showing the proximity of the Greensboro South enhancement site to the adjacent outcrop, Veazey, where naturally occurring *I. tegetiformans* was sourced and propagated for reintroduction to the enhanced Greensboro South pools (Google, 2021).



Figure 16. “Penhall contractors prep equipment for cutting. Surface water and soil were removed from the pool prior to cutting. Original soil was then replaced into the deepened pool” (Richards, 2015).



Figure 17. “Pool 2 cut to a 4” depth in crosshatched pattern. Soils excavated from the pool prior to cutting can be seen at the top of the image” (Richards, 2015). This method was used for all pools cut with a diamond blade saw. Note that here an existing depression is being deepened, not a bare rock de novo pool creation.

Heggie's Rock, Columbia County

Organizations Involved: The Nature Conservancy, Atlanta Botanical Garden, USFWS
Primary Project Partners: Jennifer Cruse-Sanders (ABG), Jimmy Rickard (USFWS), Malcolm Hodges (TNC), Debbie Harris (USFWS), Matt Richards (ABG)

The USFWS enhancement efforts at Heggie's Rock began in 2016 after the Greensboro South and Arabia Mountain projects were under way. Information reported here is based on interviews with Malcom Hodges and Jimmy Rickard, as well as project reports prepared by Matt Richards in 2015 and 2016.

Heggie's Rock is a 101-acre granite outcrop owned and managed by The Nature Conservancy in Columbia County, Georgia (Fig. 21). Pool enhancement efforts at both Heggie's Rock and Greensboro South were completed by ABG partnering with the USFWS, Plum Creek Timber, and The Nature Conservancy for the purpose of establishing additional colonies of *I. tegetiformans*, for both safeguarding and conservation purposes (Fig. 18). Heggie's Rock has one historic pool harboring the type population of *I. tegetiformans* which exhibits pristine habitat conditions – excellent water holding capacity, soil depth at least an inch, and a well-developed “pool lip” which helps retain water. In this pool *I. tegetiformans* grows abundantly and is uninhibited by competitors. However, this population was not used as the source material for any of the enhanced pools at this site. All source material came from Mt. Gemini (see below).

Prior to the efforts of USFWS, ABG, and TNC, two (2) pools at Heggie's Rock had been inoculated with *I. tegetiformans* from an adjacent outcrop, Mt. Gemini, which was actively being quarried at the time, and has since been completely obliterated by quarrying. This rescue event is not documented but occurred in the early 1980s, prior to any cutting or pool enhancement associated with the USFWS. Tom Patrick, long time botanist with GA DNR and the GA Natural Heritage Program, is believed to have spearheaded this effort. Mt. Gemini was known to have *I. tegetiformans* populations. Rescue material from those populations was transplanted from Mt. Gemini to Heggie's Rock by a Patrick-led team. An old, plastic, white bucket that laid in the woods for years near the transplant site was rumored to have been the bucket used to transport the rescue material.

These plants were transplanted into two pools, East Pool (also named Mt Gemini, or K7 in some records) and West Pool (a.k.a. K6; Fig. 20). To enhance water holding capacity and stop the outflow of water from the pool, concrete was used to effectively dam the outflow of the two pools. This enhanced the water holding capacity for each pool, allowing the species to persist. These two populations persist and thrive today. Periodic touchups have been made to the concrete additions by Malcom Hodges (per communication) but otherwise the masonry has withstood the test of time. Eric VanDeGenachte recalled hearing of the concrete addition prior to his own efforts at Rock Chapel Road but didn't remember being inspired by specific techniques. Heggie's Rock is the oldest known instance of direct pool enhancement with modifications made to the structure of the pool.

Beginning in 2016, three (3) existing pools were enhanced through deepening at Heggie's Rock by TNC and USFWS (Fig. 19). The portion of the outcrop chosen for enhancement was based on site accessibility for bringing large equipment onto the rock, as well as selecting a more secluded section of the rock that was not part of the regular loop often used for education and outreach tours. While Heggie's Rock is a private site, The Nature Conservancy permits visitors on guided tours and has an established path to reduce foot-traffic impact. Once the ideal portion of the rock was chosen, five pools were selected for enhancement based on depth and water

holding capacity. All pools considered for this project were located on the northeast side of the outcrop facilitating accessibility equipment, as well as the flat topography that would reduce waterflow and increase the success of plant introductions. Ramets of *I. tegetiformans* were collected from the existing populations in East Pool and West Pool (populated from Mt. Gemini in the 1980s). Ramets were collected and propagated at the ABG before being reintroduced into the created pools.

Of the five eligible pools, three had mats of moss and lichen that needed to be removed to properly assess the water holding capacity of each pool. With permission from TNC and partners, the moss mats and vegetation were removed from the eligible pools. All pools' water holding capacity was monitored after rains in the spring. Three were ultimately chosen for enhancement based on their ability to retain water and show no signs of leakage. They were, however, naturally too shallow to support the species and would need to be deepened using the methods established from the previous projects.

In 2016, ABG began enhancement work on the three (3) pools using diamond blade concrete saws, partnering with Penhall Contractors. The saws, attached to the front of a skid steer, cut 4" (maximum depth of saw) into the granite in a crosshatch pattern, following the same technique used at Arabia and Greensboro South (Fig. 23). The blocks of granite were then excavated from the pool and granite debris was removed from the outcrop. All cuts were successfully completed in one day. The mats of vegetation that had been removed from the pools prior were used to heal in disturbed areas where the skid steer accessed the outcrop (Fig. 22).

The cut pools were then monitored for a year to assess the water holding capacity prior to transplanting any plants. Two (2) of the three enhanced pools, Pool 1 and Pool 3, successfully held water above the 2" soil line, and thus *I. tegetiformans* was transplanted into the pools. Pools must be able to hold standing water about an inch above the soil line to be sufficient habitat for the species (Fig. 8). The enhanced pools were filled with the soil that had been removed from them originally as well as with native soil taken from surrounding pools. Malcolm Hodges noticed that Pool 2 had a crack and was not sufficient for *I. tegetiformans* because it wouldn't hold water to the correct depths. To make use of the new pool, *G. amphiantha* was transplanted to Pool 2 from an adjacent, naturally occurring population. *Gratiola amphiantha* can withstand larger fluctuations in hydrologic period than can *I. tegetiformans*, making this pool suitable habitat for *G. amphiantha* but not *I. tegetiformans*.

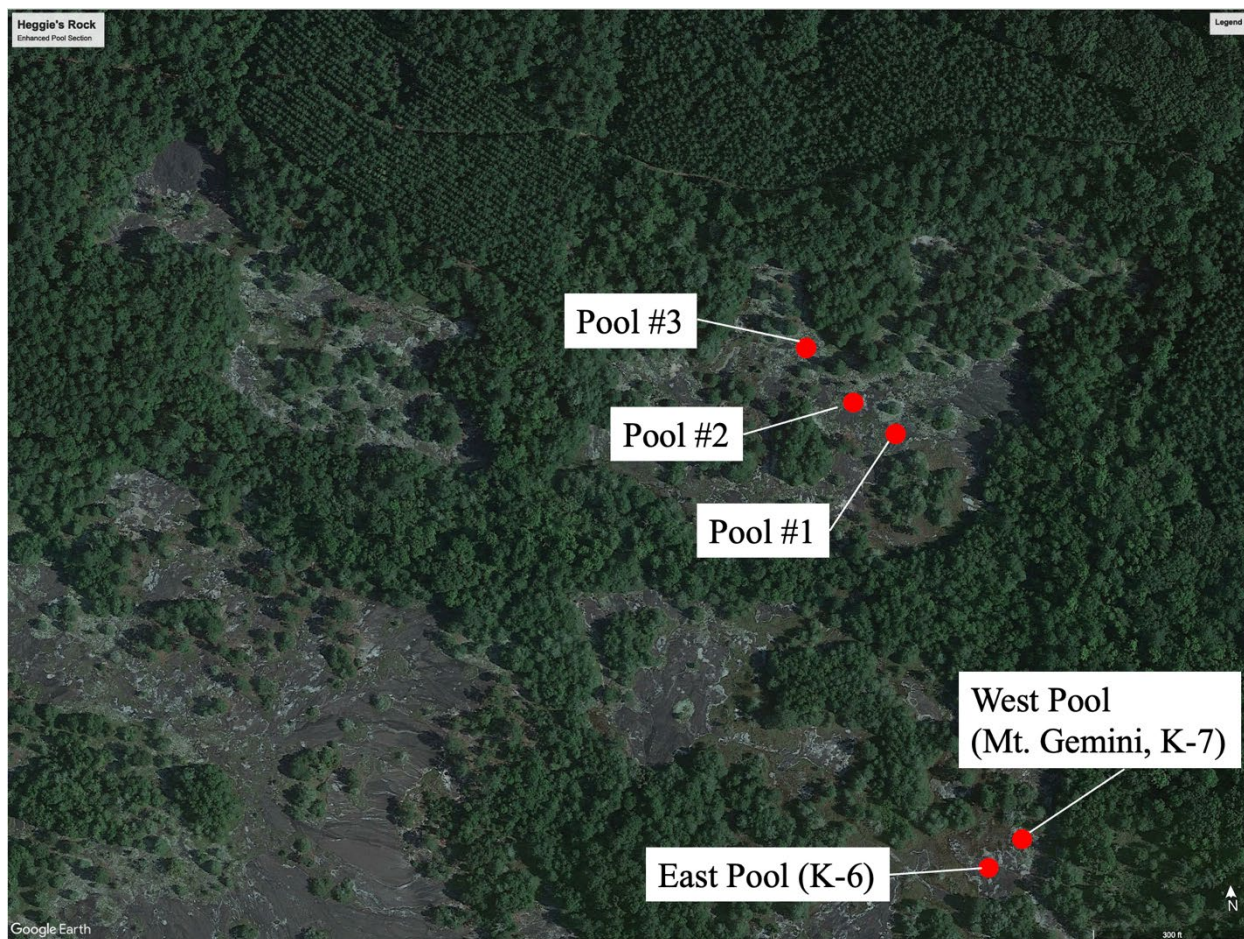


Figure 18. Map of Heggie's Rock showing enhanced pools as red waypoints. Coordinates for each pool are available in Table 3 (Google, 2021).

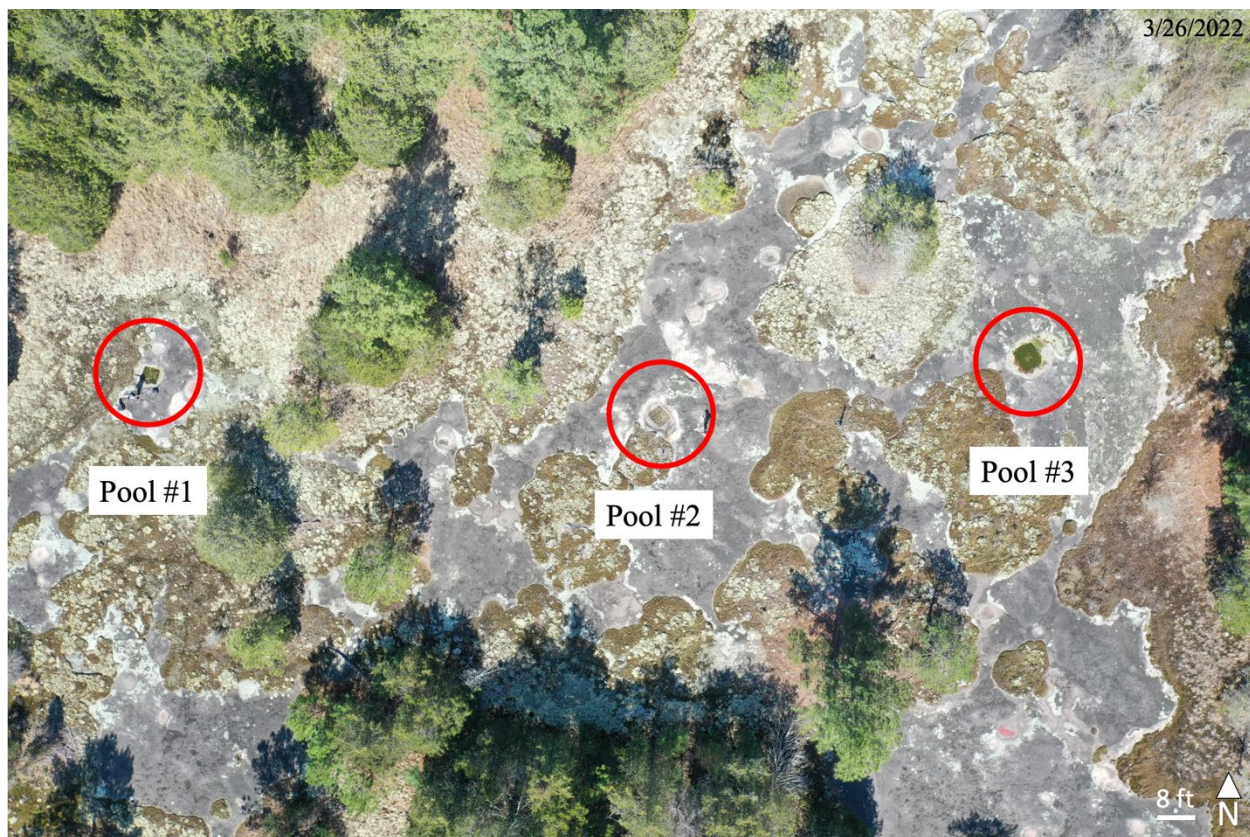


Figure 19. Pools 1-3 at Heggie's Rock. Taken on a DJI Mavic Pro drone on 3/26/2022.

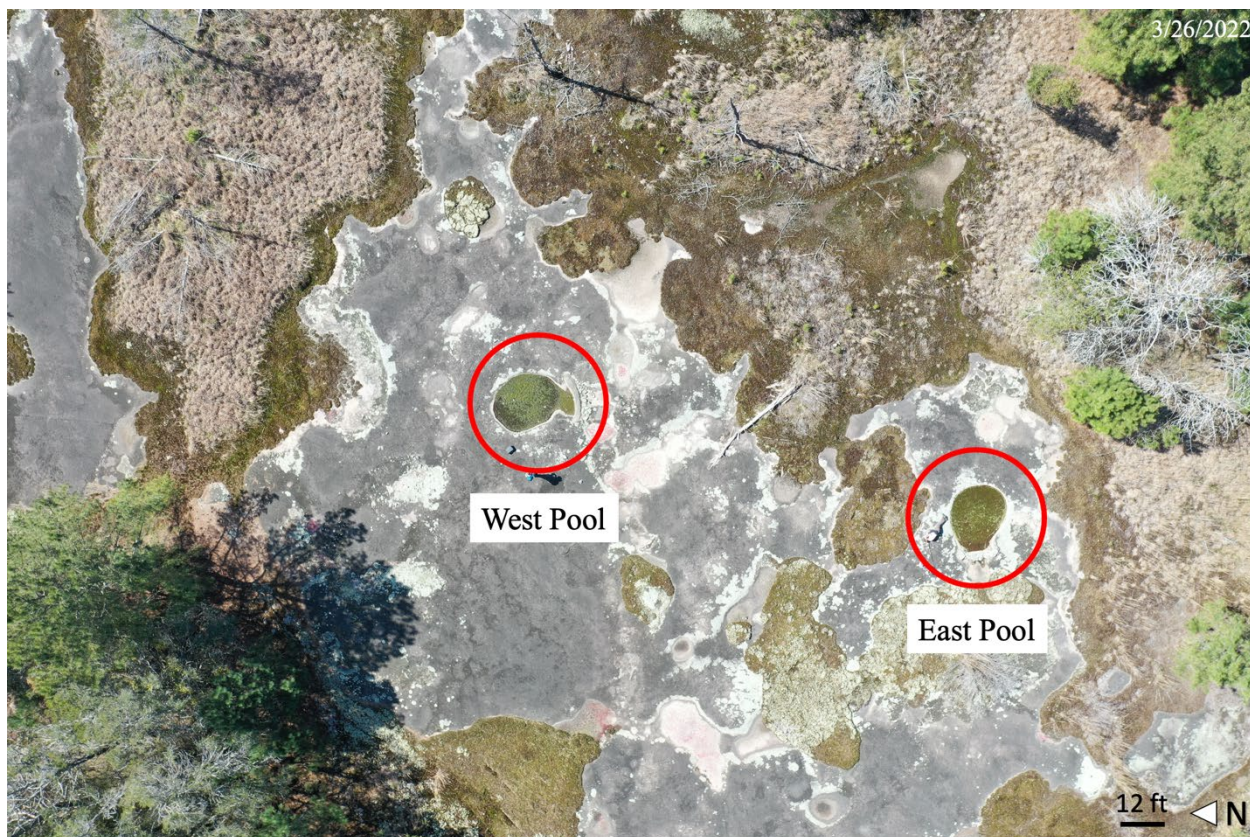


Figure 20. West Pool and East Pool at Heggie's Rock. Taken on a DJI Mavic Pro drone on 3/26/2022.

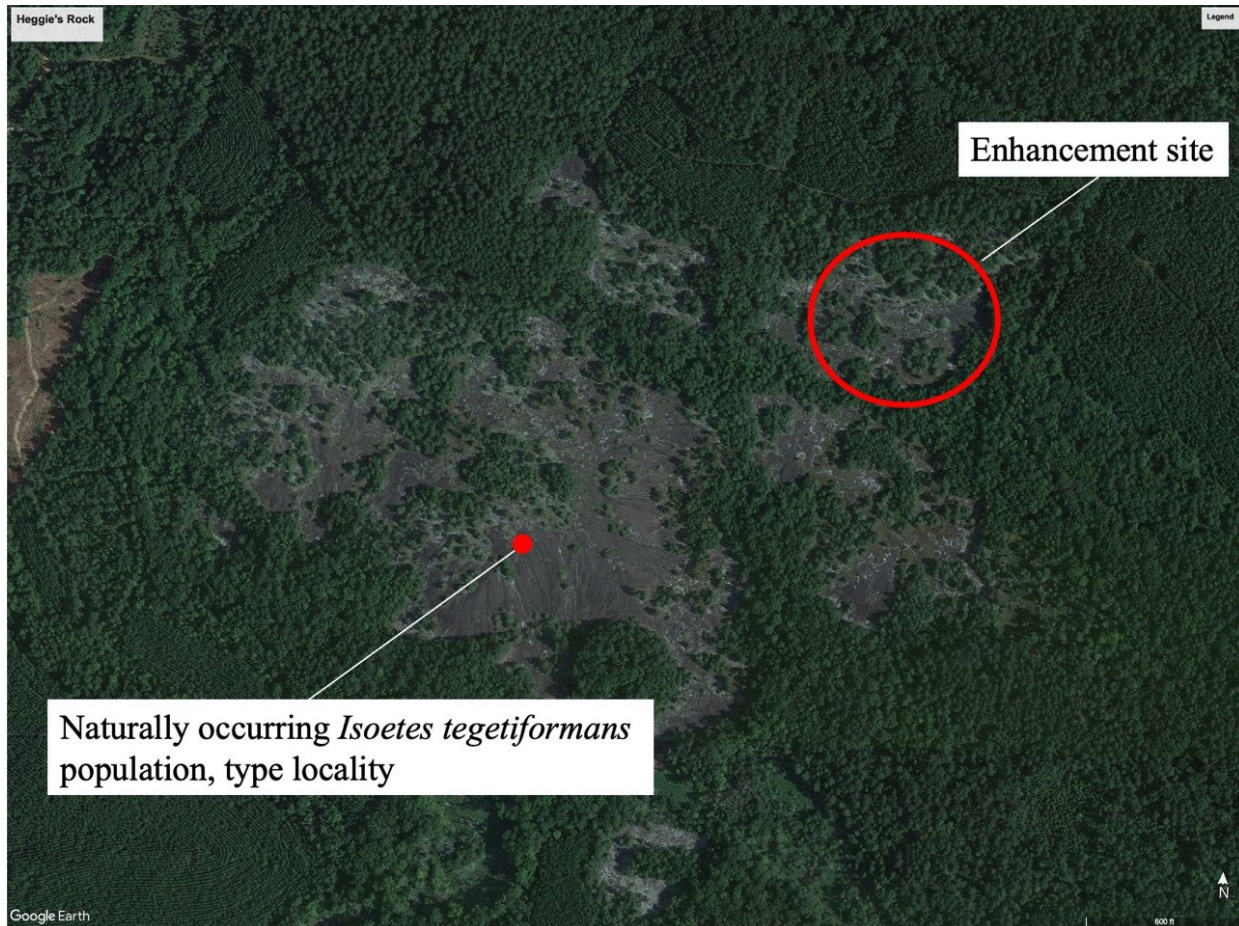


Figure 21. Map of Heggie's Rock showing the location of the single, naturally occurring *Isoetes tegetiformans* population (the type locality for the species) as a red dot, and the location of the enhancement efforts as a red ellipse (Google, 2021).



Figure 22. Penhall contractors use a diamond blade wet concrete saw to create cuts in the pools. Notice the truck in the staging area (top left) and the mats of mosses and *Selaginella* in the foreground. These mats of vegetation would be utilized to heal-in disturbed areas where the skid steer accessed the outcrop (Richards, 2016).



Figure 23. Excavation of overburden in Pool #3 at Heggie's Rock. Overburden was removed by wheelbarrow from the outcrop (Richards, 2016).

Current Status and Assessment of Efforts

In the spring of 2022, project sites were visited and enhanced pools were surveyed, mapped, and photographed (excluding the now extirpated Rock Chapel Road). Greensboro South, Arabia Mountain, and Heggie's Rock were visited again in 2023. For each population, an estimated percent cover of rare species was recorded (Table 3). In 2015 and 2017, percent cover estimates had been made for the enhanced pools at Arabia, inspiring the type of data collected here. Drone photographs were also taken of all existing pools except for those at Stone Mountain where high winds prevented safe flying of the drone at the time of survey. These photos provide an overhead image of pools which can be used to verify percent cover estimates, as well as provide the opportunity to compare pool status from year to year. A high-precision GPS unit (Eos Arrow Gold RTK unit) was used to map each enhanced pool, creating site maps in Esri's Field Maps app. The centroids of each pool were recorded from these maps and are provided here. These maps will be provided as shapefiles to the USFWS accompanying this report. At almost a decade old, the enhancement projects may be reasonably assessed to be successful or not. Drone images were taken using a DJI Mavic Pro.

Table 3. Contains all percent cover estimates collected for the purposes of this report, as well as prior to the report by project partners (data were collected at Arabia Mountain in 2015 and 2017). Cells with two percentages represent percent cover estimates for the *Isoetes* species present, followed by the *Gratiola amphiantha* percentages, if applicable. *Isoetes melanospora* is present at Stone Mountain and Arabia Mountain. *Isoetes tegetiformans* is present at Greensboro South and Heggie's Rock. Rock Chapel Road is omitted here because there is no record of the pool's exact location nor of percent cover estimates because the site is destroyed. * SM10 was observed for first time by author in 2024 and added to Version II of this report.

Site	Pool	Lat	Long	2015 % Cover	2017 % Cover	2022 % Cover	2023 % Cover
Stone Mtn.	Exp. 1	33.8	-84.1	NA	NA	0	NA
Stone Mtn.	Exp. 2	33.8	-84.1	NA	NA	0, <5	NA
Stone Mtn.	Exp. 3	33.8	-84.1	NA	NA	0, 35	NA
Stone Mtn.	SM1	33.8	-84.1	NA	NA	70, <5	NA
Stone Mtn.	SM2	33.8	-84.1	NA	NA	15, 10	NA
Stone Mtn.	SM3	33.8	-84.1	NA	NA	0	NA
Stone Mtn.	SM4	33.8	-84.1	NA	NA	15, 20	NA
Stone Mtn.	SM5	33.8	-84.1	NA	NA	10, 15	NA
Stone Mtn.	SM10	33.8	-84.1	NA	NA	NA	5, <5*
Stone Mtn.	PoolA	33.8	-84.1	NA	NA	0	NA
Stone Mtn.	PoolB	33.8	-84.1	NA	NA	0	NA
Stone Mtn.	PoolC	33.8	-84.1	NA	NA	0	NA
Arabia Mtn.	C1	33.6	-84.1	25, <5	10	25	20
Arabia Mtn.	C2	33.6	-84.1	25	40	15	20
Arabia Mtn.	C3	33.6	-84.1	30	40	25	35
Arabia Mtn.	C4	33.6	-84.1	0	<5	<5	<5

Arabia Mtn.	C5	33.6	-84.1	25	50	45	80
Arabia Mtn.	C6	33.6	-84.1	5, <5	15, <5	25, 5	20, <5
Arabia Mtn.	C7	33.6	-84.1	5, <5	10, 5	10, 15	5, 5
Arabia Mtn.	C8	33.6	-84.1	5	15, <5	15, 20	15, 5
Arabia Mtn.	C9	33.6	-84.1	<5, <5	15, <5	5, 10	<5, 5
Arabia Mtn.	C10	33.6	-84.1	<5	5, 10	<5, 15	<5, 15
Greensboro	Pool 1	33.4	-83.1	NA	NA	<5	<5
Greensboro	Pool 2	33.4	-83.1	NA	NA	90	95
Greensboro	Pool 3	33.4	-83.1	NA	NA	95	95
Greensboro	Pool 4	33.4	-83.1	NA	NA	0	0
Greensboro	Pool 5	33.4	-83.1	NA	NA	0	0
Greensboro	Kyla's	33.4	-83.1	NA	NA	45	80
Greensboro	Pete's	33.4	-83.1	NA	NA	<5	5
Heggie's	1	33.5	-82.2	NA	NA	95	95
Heggie's	2	33.5	-82.2	NA	NA	0, 45	0, 45
Heggie's	3	33.5	-82.2	NA	NA	95	95
Heggie's	East	33.5	-82.2	NA	NA	95, <5	85, <5
Heggie's	West	33.5	-82.2	NA	NA	95, <5	85, <5

Table 4. Breakdown of the number of natural, enhanced, and established pools at each site. The number of natural *Isoetes* pools is the number of pools with either *Isoetes* spp. at a site prior to any enhancement (*Isoetes melanospora* (ISME3), and *Isoetes tegetiformans* (ISTE)). Bolded cells are enhanced pool counts. The number of enhanced pools (with or without inoculation) refers to the number of pools that were enhanced in ways other than deepening existing depressions or de novo creation (weeding, concrete wall, etc.). Shattering top layer of friable granite with steel rod is considered enhancement. Only deepening with saws and jackhammers is considered deepening. De novo creation (with or without inoculation) refers to pools that were created de novo from bare rock and either received transplants of *Isoetes* or did not. Deepened (with or without inoculation) refers to the deepening of existing depressions either inoculated with *Isoetes* transplants, or not. One pool at Heggie's Rock was deepened and successfully inoculated with *G. amphiantha* (GRAM3) – it is considered an ISME3 failure but is a success for *G. amphiantha*. The total number of enhanced pools is the sum of all pools receiving any type of treatment (enhancement, deepening, creation). The number of established *Isoetes* or *G. amphiantha* pools is the total number of pools demonstrating successful establishment of any of the conservation species in 2022/2023. This count does not include those pools that already had the species (i.e., SM1, SM2, and EXP3), even if they received enhancement, it is strictly a count of newly created occurrences that would not have established without the direct efforts reported here. * SM10 was observed for first time by author in 2024 and added to Version II of this report.

Site	Natural <i>Isoetes</i> Pools	Enhanced (w/o inoc / w/ inoc)	De novo created (w/o inoc / w/ inoc)	Deepened (w/o inoc / w/ inoc)	Total Enhanced Pools	Established <i>Isoetes</i> Pools	Established <i>G. amphiantha</i> Pools
Rock Chapel Road	1 (ISME3)	0 / 0	0 / 0	0 / 1	1	0 (1 was inoculated)	0
Stone Mtn.	2 (ISME3)	5 / 4	0 / 2	1 / 0	12	3 (6 were inoculated)	4
Arabia Mtn.	8 (ISME3)	0 / 0	0 / 8	0 / 2	10	10 (10 were inoculated)	5
Greensboro	0 (ISTE)	0 / 1	0 / 0	1 / 5	7	5 (6 were inoculated)	0
Heggie's	1 (ISTE)	0 / 2	0 / 0	1 / 2	5	4 (4 were inoculated)	2

Stone Mountain, DeKalb County

Summary of Success at Stone Mountain:

The enhancement projects at Stone Mountain must largely be considered a success. Introductions of *I. melanospora* have been established and have reproduced to sustain themselves. There are no historic estimates of the *I. melanospora* populations and thus only 2022 percent cover estimates are included in Figure 24. Through these efforts, two (2) additional populations of *Isoetes melanospora* have been established (although three (3) were attempted) and the two historic populations of the species have continued to persist. The pool deepening efforts using jackhammers were not successful in establishing new *I. melanospora* pools, demonstrating the limitations of jackhammers to deepen pools to required depths for *Isoetes*. The establishment of *G. amphiantha* has also been successful in many of the enhanced pools (Fig. 25).

On March 30, 2022, Anna Wyngaarden, Mincy Moffett, Larry Winslett, and Josh Griffith (Lands Management Supervisor at SMMA) visited and surveyed the enhanced pools at Stone Mountain. Winslett discussed the history of each pool and the efforts applied to them. Pools were mapped using the ArrowGold GPS unit. The drone was flown for a few moments but was then landed because the wind was too strong at the summit of the mountain and the fog was dense (Fig. 26). Photos were then taken on an iPhone. At the time of survey, there was no standing water in the pools. Percent cover estimates of persisting *Isoetes melanospora* populations were recorded.

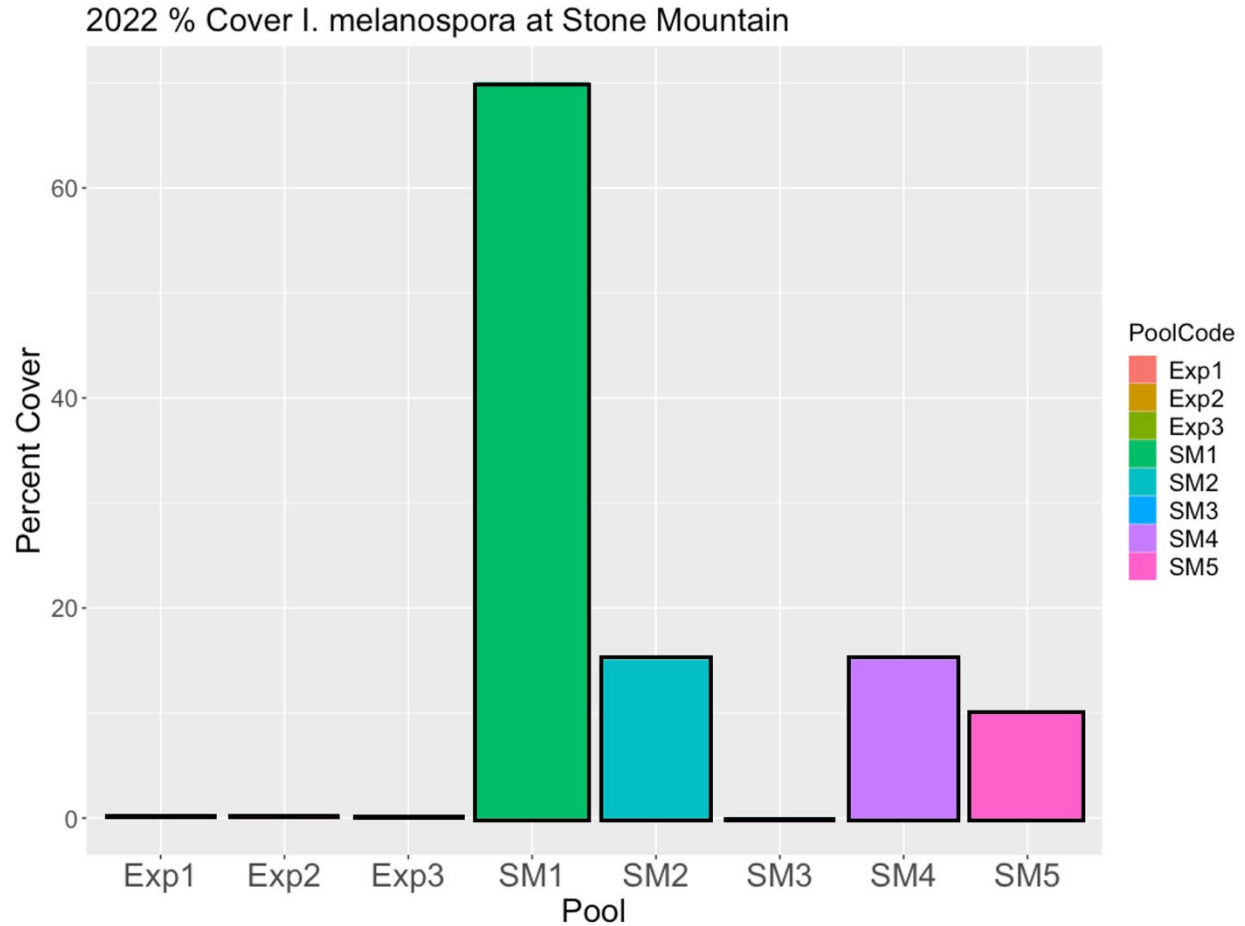


Figure 24. Percent cover estimates of *I. melanospora* in enhanced Stone Mountain pools in 2022. SM1 and SM2 are the historic populations of *I. melanospora*. The species was transplanted into Exp3, SM3, SM4, and SM5. Exp1 and Exp2 did not receive *I. melanospora* transplants. Pools A, B, and C are omitted because they support neither of the target species. These data are available in Table 3. * SM10 was added to the Version II of this report in 2024. It does not appear in the graph.

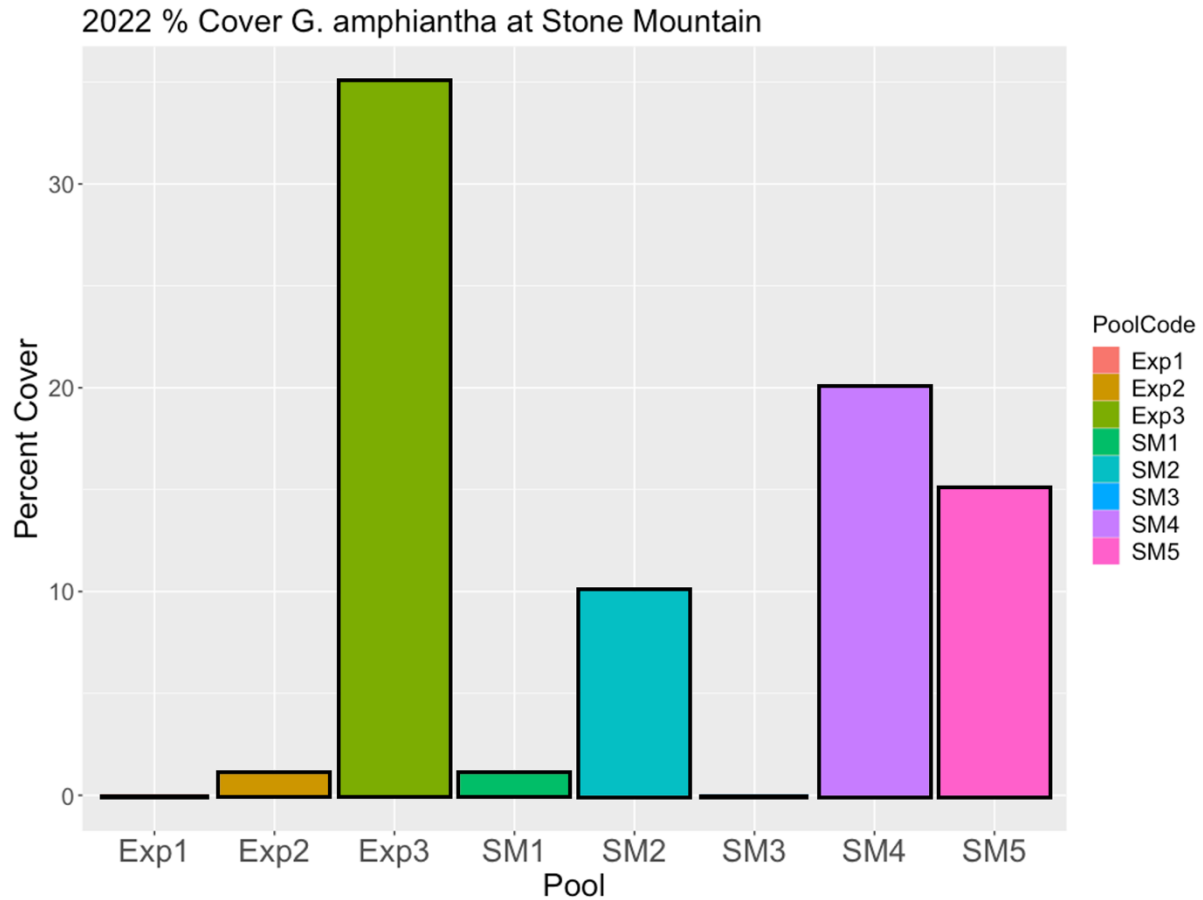


Figure 25. Percent cover estimates of *G. amphiantha* in enhanced Stone Mountain pools in 2022. Pools A, B, and C are omitted because they support neither of the target species. These data are available in Table 3. In-field measurements of “<5%” are entered as 1% here. * SM10 was added to the Version II of this report in 2024. It does not appear in the graph.



Figure 26. 4/5/2022. Enhanced area within the fence on top of Stone Mountain with Experiment 1 in the foreground. Weather conditions were too windy and poor to fly the drone for photographs.



SM1, 4/5/2022

Enhancement: A historic population of *I. melanospora* that has been used for source material to populate other pools at Stone Mountain. Competing vegetation is weeded to maintain the *I. melanospora* population. Soil and plant material were removed from this pool and have been cultivated in plastic Tupperware trays on Stone Mountain's campus, off the main monadnock. *Gratiola amphiantha* also grows in this pool. The arrow points to the portion of the pool supporting *I. melanospora*.

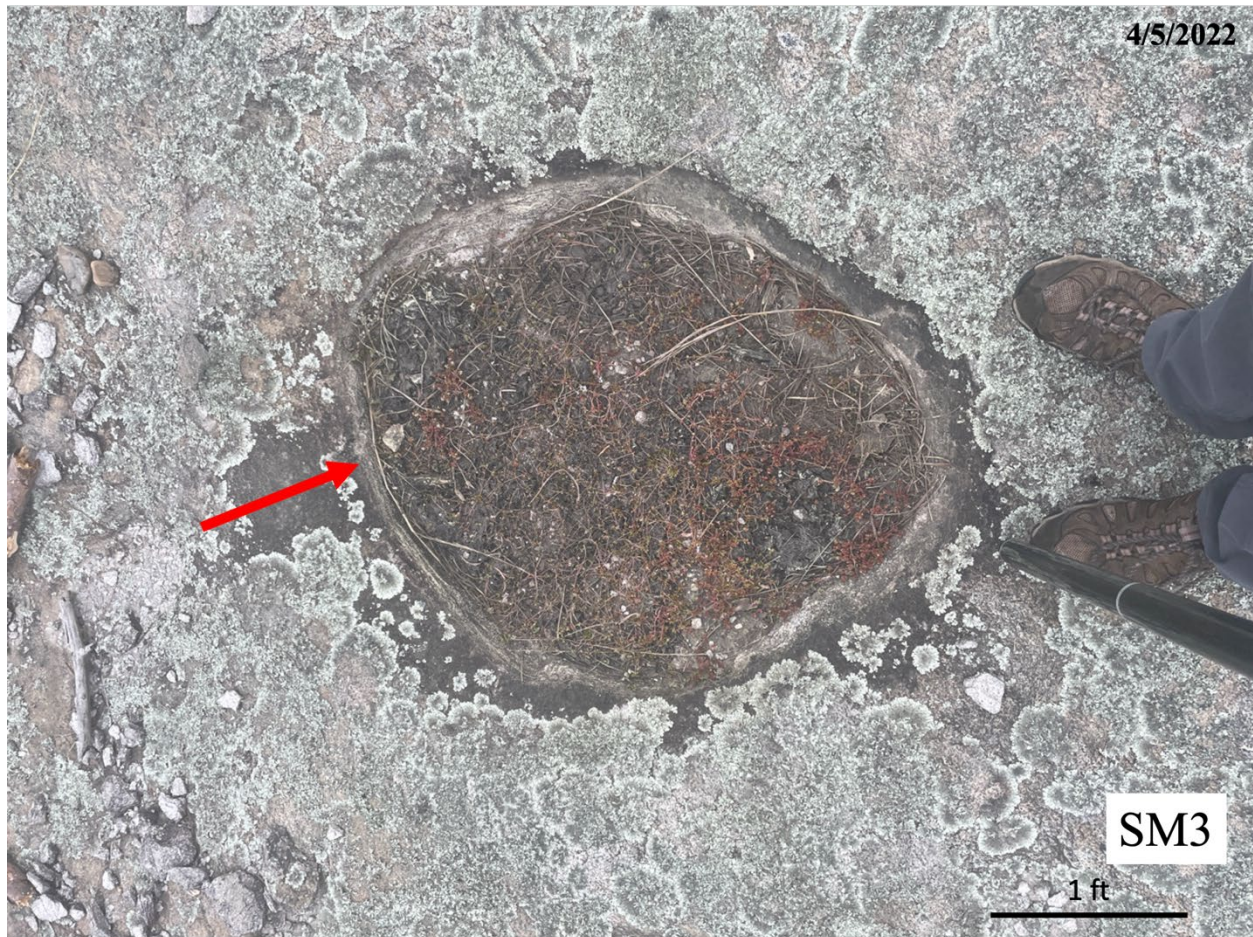
Outcome: This *I. melanospora* in this pool continues to persist. Efforts weeding competing vegetation are successful and allow the species to thrive.



SM2, 4/5/2022

Enhancement: This is a natural population of *I. melanospora* and is maintained through weeding competitive plant material (mainly *Juncus* sp.). Dotted line shows to the boundary of where *Juncus* and competing vegetative material are weeded.

Outcome: *Isoetes melanospora* and *G. amphiantha* persist in this pool and weeding competitive material is a success to maintain enough suitable pool habitat for the species.



SM3, 4/5/2022

Enhancement: This pool was created de novo using a jackhammer (arrow points to shattered edge). *Isoetes melanospora* was intentionally transplanted (and *G. amphiantha* incidentally) from propagation trays in 2009, but neither persist. *Diamorpha smallii* grows in the soil that has since accumulated but no species of conservation concern are found in this pool, likely because it is too shallow, at just below 2 inches deep. Deepening this pool to at least 4 inches is recommended before further reintroductions.

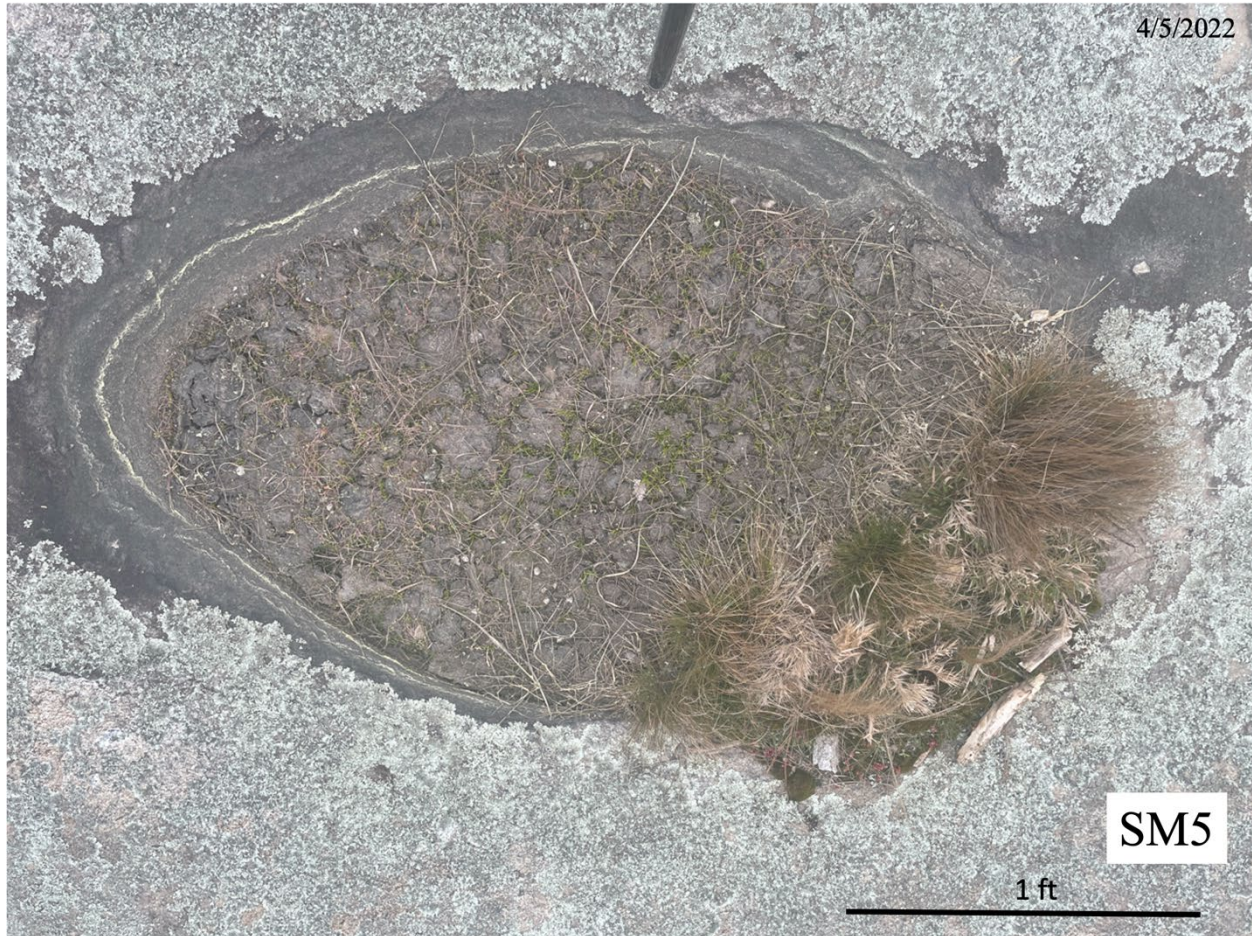
Outcome: This pool is not a success and neither of the transplanted species persist, likely due to being too shallow, demonstrating the limitations of jackhammers for deepening pools. The pool is recommended for deepening to twice its current depth to support either *I. melanospora* or *G. amphiantha*.



SM4, 4/5/2022

Enhancement: This pool was created de novo using a jackhammer and *I. melanospora* was transplanted from the cultivated SM1 population. A vegetation dam was also created by planting *Juncus* in the pool where water flows into the pool (red arrow). This minimizes the potential of washout in large rainfalls. *Gratiola amphantha* also persists in this pool.

Outcome: This pool is successful with *I. melanospora* persisting in 2022. The vegetation dam buffering water flow into the pool likely allows for persistence of both the *I. melanospora* and *G. amphantha* populations.



SM5, 4/5/2022

Enhancement: *Isoetes melanospora* was transplanted into this existing pool in 2014 and persists. No other enhancements were made to the pool structure. *Gratiola amphiantha* also persists and was introduced into the pool either through the *I. melanospora* transplant or through natural migration from adjacent populations. Competing vegetation (mainly *Juncus*) is routinely weeded from the pool.

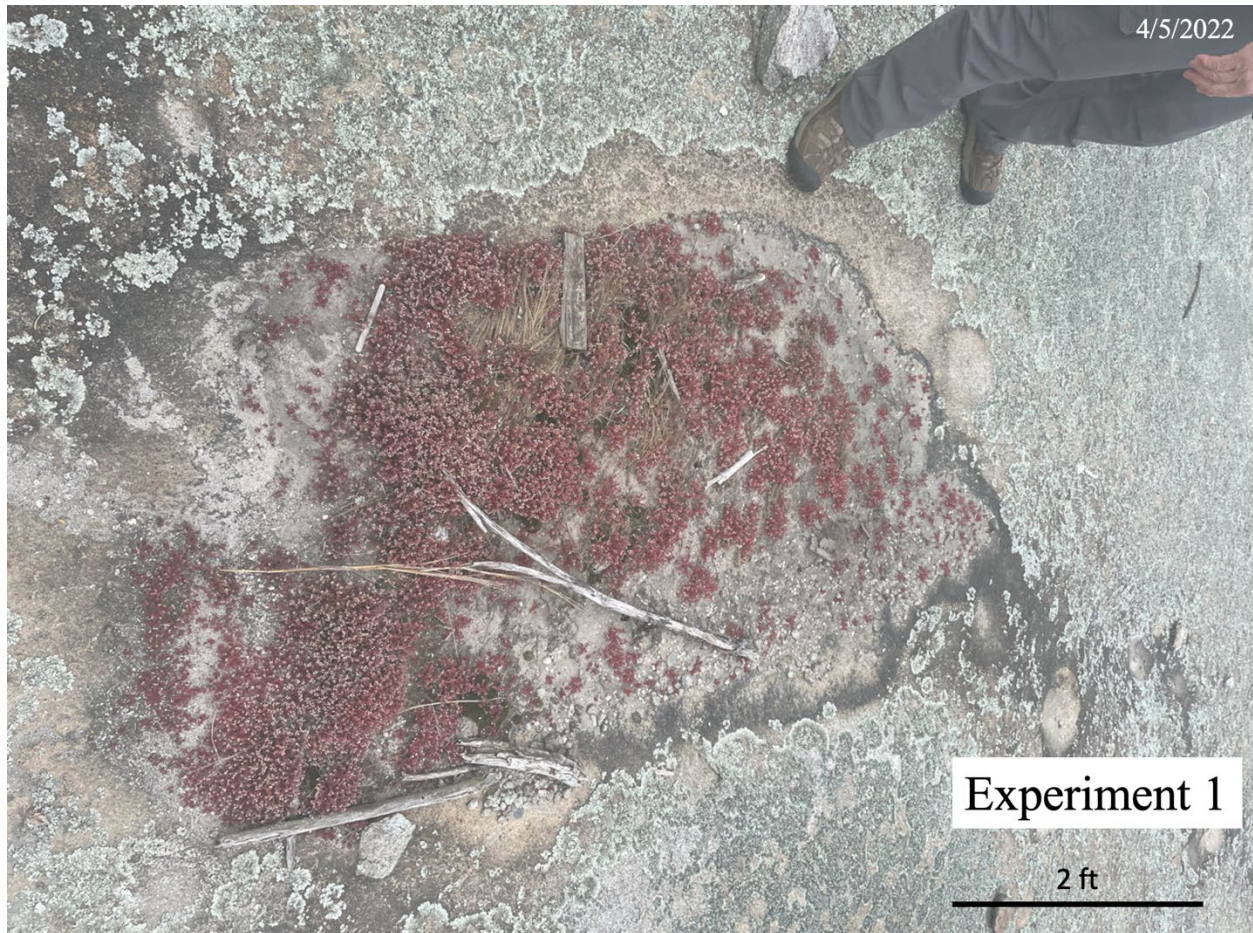
Outcome: *Isoetes melanospora* and *Gratiola amphiantha* persist in the pool and maintain robust populations.



SM10, 4/20/2024

Enhancement: This was an existing pool with no target species. This pool was inoculated using the soil from roots of weeded material from SM2 in 2015. Both *Isoetes melanospora* spores and *Gratiola amphiantha* seeds were likely present in the soil. No other enhancements were made to the pool structure.

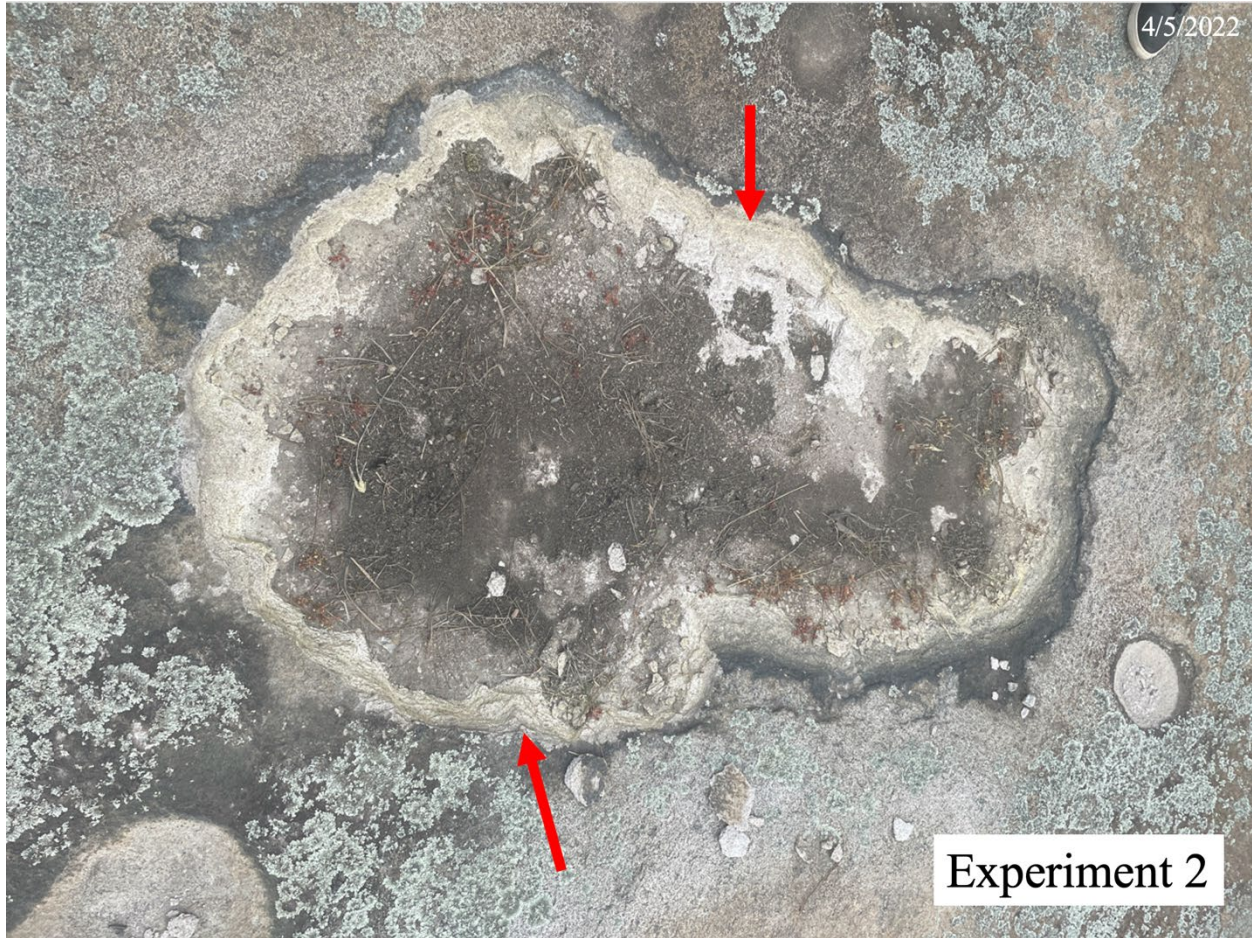
Outcome: *Isoetes melanospora* and *Gratiola amphiantha* persist in the pool and maintain small populations.



Experiment 1, 4/5/2022

Enhancement: Soil was fully removed in 2016 to see how quickly plant life would establish. Soil has accumulated enough to support *D. smallii* by 2022. No species of conservation concern were introduced to or inhabit this pool, but the amount of soil accumulated within seven (7) years demonstrates the speed at which succession can occur in these habitats.

Outcome: This pool did not receive transplants of either species and has not been evaluated for suitability. The pool is likely not deep enough to support either species but is successful in showing the speed at which outcrop pools can accumulate soil and establish vegetation growth.



Experiment 2, 4/5/2022

Enhancement: Native soil was removed, and the pool was deepened with a jackhammer in 2019 to a couple inches deep. The jackhammer was only able to remove the top layer of granite and was limited in its ability to create a deeper pool. Red arrows point to areas the jackhammer chipped away. *Gratiola amphiantha* has repopulated the pool, with a few plants found in 2022.

Outcome: This pool is a relative success, supporting a new population of *G. amphiantha*, but is not expected to support *I. melanospora* based on its limited depth. This pool demonstrated the limitations of a jackhammer in deepening pool habitat.



Experiment 3, 4/5/2022

Enhancement: *Gratiola amphiantha* naturally grows in this pool. *Isoetes melanospora* was transplanted from the historic pool in 2014 but does not persist in 2022, presumably because the pool is too shallow. Large amounts of pine debris may be an additional stressor for *I. melanospora*.

Outcome: *I. melanospora* transplant was initially successful, persisting in 2016. It was not found in 2022. *G. amphiantha* was present at the time of survey.



Figure 27. The remaining outcrop surrounded by parking lots and buildings at the base of Stone Mountain. Pool A is pictured in the foreground, with Mincy Moffett (USFWS), Josh Griffith (SMMA), and Larry Winslett (SMMA). In the distance is the Stone Mountain Museum.



Pool A, 4/5/2022

Enhancement: A concrete lip was added to the top of the pool in 2016 where water flows into the pool but is no longer there (red arrows). *Isoetes melanospora* was also transplanted into the pool in 2016.

Outcome: None of the transplanted *I. melanospora* remain and the concrete lip has deteriorated either due to poor application or high visitor traffic. The efforts in this pool were not successful. Future efforts will need to experiment with a better concrete lip seal and efforts to discourage foot traffic.



Pool B, 4/5/2022

Enhancement: A concrete lip, or dam, was added in 2016 to the point of water inflow, but the concrete is no longer there (red arrows).

Outcome: No species were transplanted into this pool and the concrete addition was obsolete within at least 2 years of application, likely due to high visitor traffic. This pool was not successful because of the quick deterioration of the concrete addition.



Pool C, 4/5/2022

Enhancement: A concrete lip, or dam, was added in 2016 to the point of water inflow.

Outcome: This pool is not considered successful because of the quick deterioration of the concrete addition. No species were transplanted into this pool and the concrete addition was obsolete within at least 2 years of application, likely due to high visitor traffic

Arabia Mountain, DeKalb County

Summary of Success at Arabia Mountain:

The enhancement projects at Arabia Mountain have undoubtedly been successful. These efforts have effectively established ten (10) new populations of *I. melanospora* of which five (5) also support *G. amphiantha* populations (Fig. 28; Fig. 29). The most successful populations of *I. melanospora* have minimal competing vegetation and have been cut to a proper depth for holding water and soil. Those populations that are less successful have overgrowths of algae, competing vegetation, or were cut unevenly (unlevel pool bottom) which results in areas of the pools too shallow to support *I. melanospora*. All pools continue to hold water to desirable depths of 1-2" above soil lines.

The two pools in Site B (Phase 1) have larger amounts of competing vegetation than Site A (Phase 1; Fig. 30) or Phase 2. This is likely due to the proximity of Site B to surrounding fully vegetated habitats, particularly the edge of the outcrop where more perennial growth persists (Fig. 31). Both Site A and Phase 2 are on portions of outcrop located many meters away from established perennial growth. *Juncus* is a clear competitor for the establishment of *I. melanospora* and *G. amphiantha* and should be removed from pools with care as it is often interspersed with *I. melanospora*. Roots of removed plant should be rinsed back into pool to return any propagules.

Arabia Mountain was surveyed in both 2022 and 2023 by Wyngaarden. Phase 1 and Phase 2 were surveyed on April 15, 2022 and percent cover estimates of the species were recorded. At the time of the first survey, the drone was being repaired. Wyngaarden returned on May 19, 2022 to photograph the pools using the drone. Phase 2 was surveyed and photographed again on February 16, 2023. Phase 1 was later surveyed and photographed on March 16, 2023.

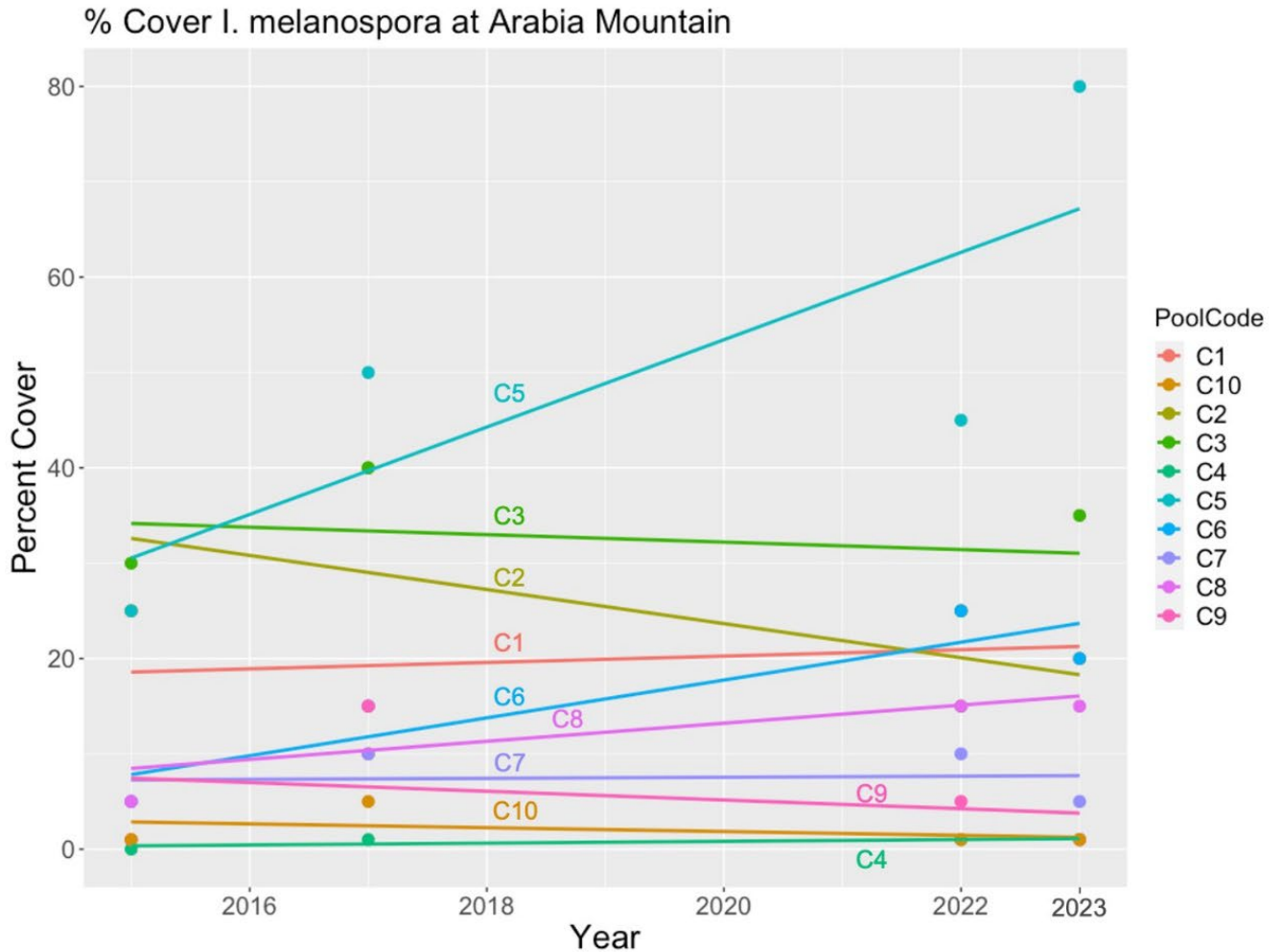


Figure 28. The percent cover of *I. melanospora* in the enhanced pools at Arabia Mountain has generally increased or seen little growth or decline since they were created. Linear regressions are of each pool's percent cover measurements over time. Individual pools are colored according to the legend. Percent cover data from 2015 and 2017 were collected by original project partners and data from 2022 and 2023 were collected by Anna Wyngaarden. Future surveys are encouraged to continue monitoring population growth or decline. These data are available in Table 3. In-field measurements of "<5%" are entered as 1% here.

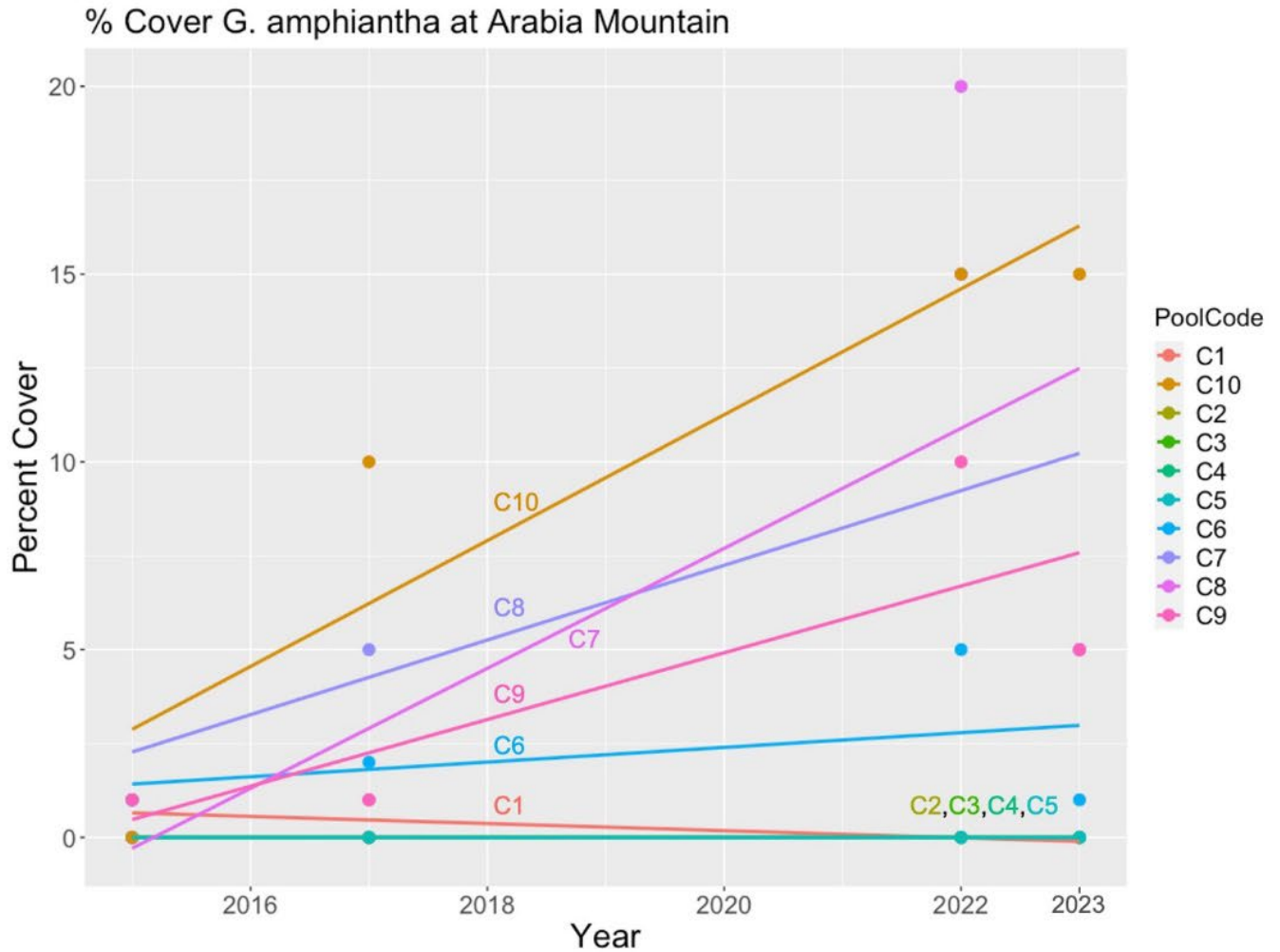
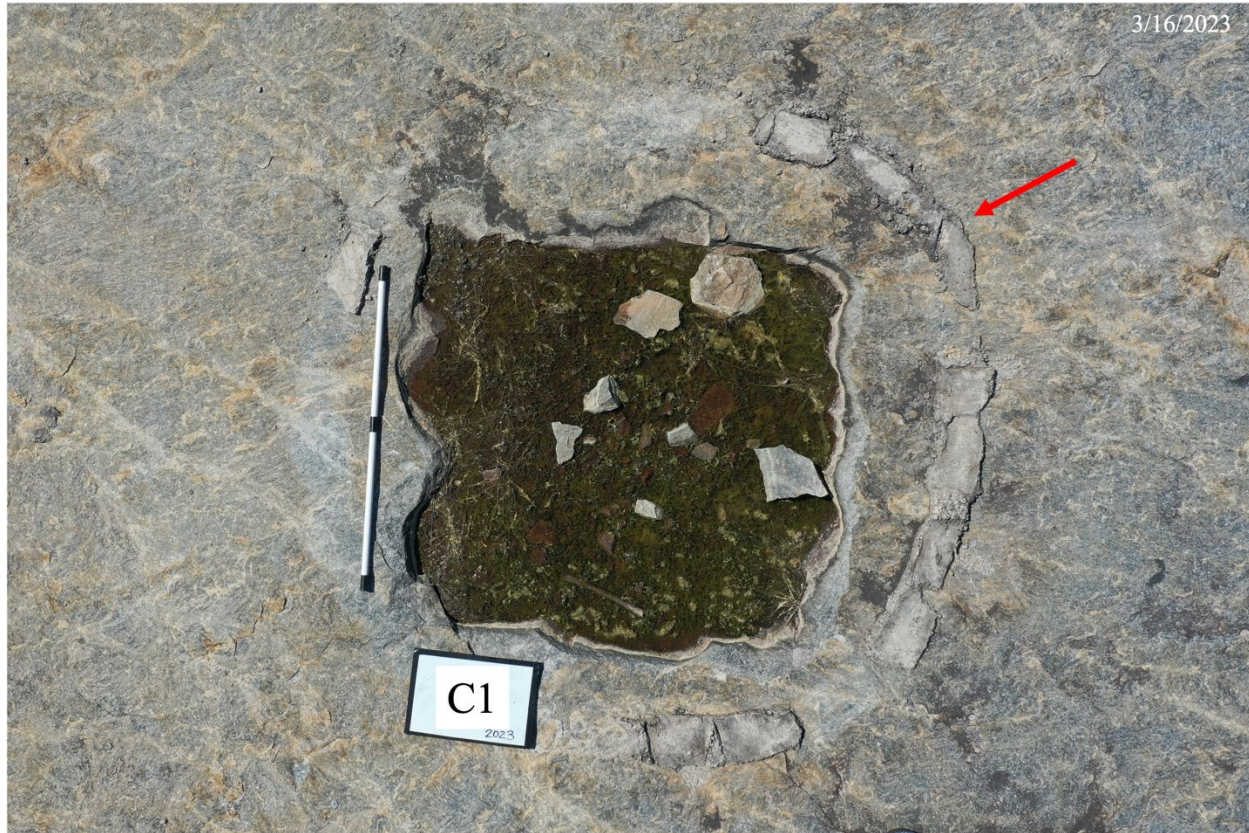


Figure 29. The percent cover of *G. amphiantha* in the enhanced pools at Arabia Mountain has generally increased since they were created. Linear regressions are of each pool's percent cover measurements over time. The percent cover of C2, C3, C4 and C5 remain 0 every year (the dots and lines for C2, C3, and C4 are not visible because they are beneath the visible C5). Percent cover data from 2015 and 2017 were collected by original project partners and data from 2022 and 2023 were collected by Wyngaarden. Future surveys are encouraged to continue monitoring population growth or decline. In 2016, the species covered 1% of C1 (red dots and line) and was absent the following years. These data are available in Table 3. In-field measurements of "<5%" are entered as 1% here.

Phase 1, Site A Pools:



C1, 3/16/2023. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length.

Enhancement: Pool was created de novo from bare rock. Soil and plants were transplanted into the created pool.

Outcome: *Isoetes melanospora* persists in 2022 and appears to be reproducing and/or stabilizing at around 20% cover in 2023 after starting around 25%, dropping to 10% in 2017, and then returning to 20% in 2023. This variation may be due to differences in estimates between observers. There were 101-500 *I. melanospora* plants in 2023. The population seems to be limited only by rocks and, potentially, by frequently occurring algal growth.

Notes: Note the remnant wall left around the pool (red arrow). There are substantially sized rocks in the pools that, if removed, would likely provide more space for the *Isoetes melanospora* to populate. No *G. amphiantha* has been found in this pool and no natural populations of the species are in proximity. It can be seen from 2022 to 2023 that the rocks are arranged in different ways suggesting human impact on the pool populations. The water in 2023 was murky with algae with no obvious source of nutrients or run-off. The algal growth was only seen in C1 and C2 of Phase 1 and is of concern. The water holding capacity and soil depth of this pool is supportive of a robust *Isoetes melanospora* population and likely encourages algae growth. There is no outflow for nutrient accumulation promoting algal growth. There is minimal competing plant vegetation in this pool during the *I. melanospora* growing season.



C2, 3/16/2023. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length.

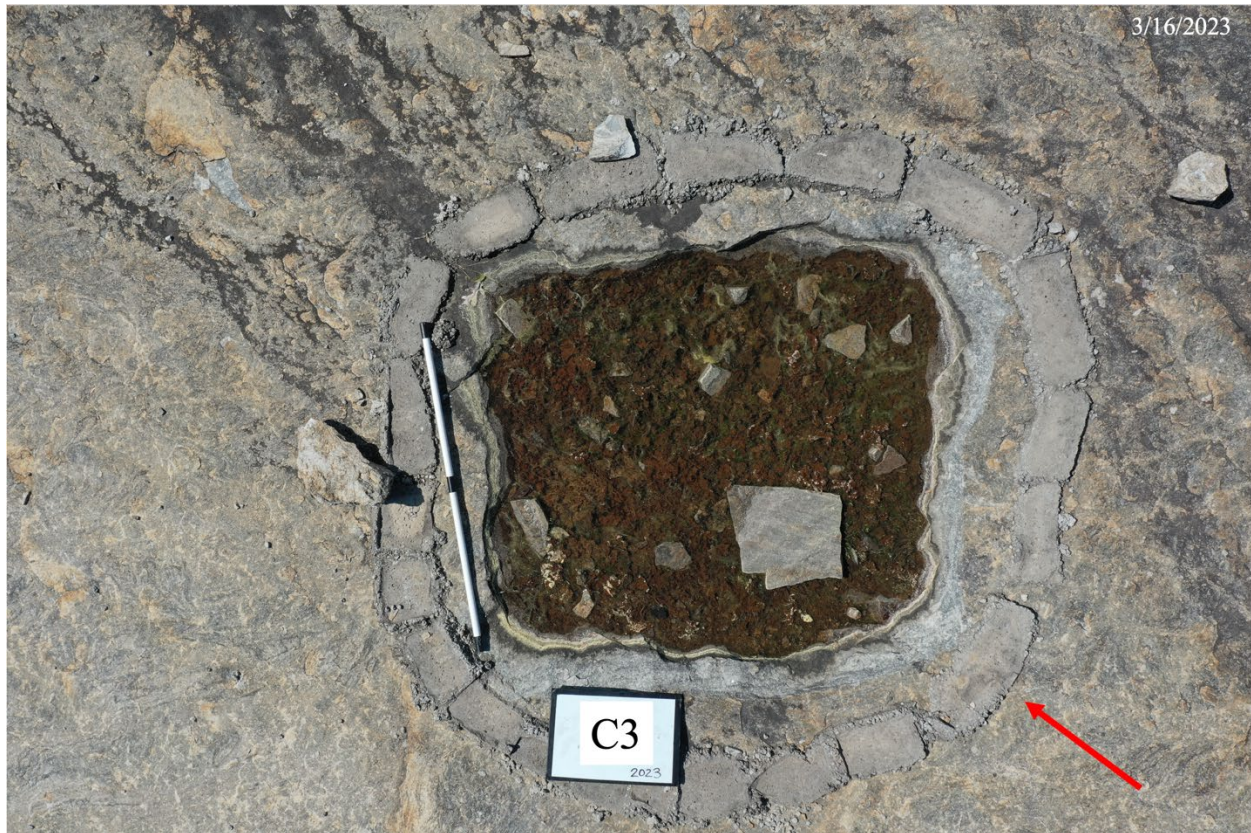
Enhancement: Pool was created de novo from bare rock. Soil and plants were transplanted into the created pool.

Outcome: *Isoetes melanospora* persists in 2023. It appears to be fluctuating as it's percent cover estimate has fluctuated from 25% cover to 40% cover to 20% cover between 2015 to 2023. The amount of algae present in this pool may hinder the population size from year to year.

Additionally, it may impact the percent cover estimate depending on the presence of the algae at the time of survey. There were 101-500 *Isoetes melanospora* plants in 2023.

Notes: The red arrow shows the remnant wall (Fig. 13). Similarly, to C1, there are substantially sized rocks in the pools that, if removed, would likely provide more space for the *I. melanospora* to populate. There is no *G. amphiantha* in this pool. Analysis of photos taken in 2022 and 2023 show the rocks arranged in different ways suggesting human impact on the pool populations.

Pools were photographed later in the season in 2022 and showed more competitive plant growth in the pools albeit the growth occurred towards the end of the season when it likely causes little impending competition to the *I. melanospora* populations. This pool has large amounts of algae present which may hinder *I. melanospora* growth.



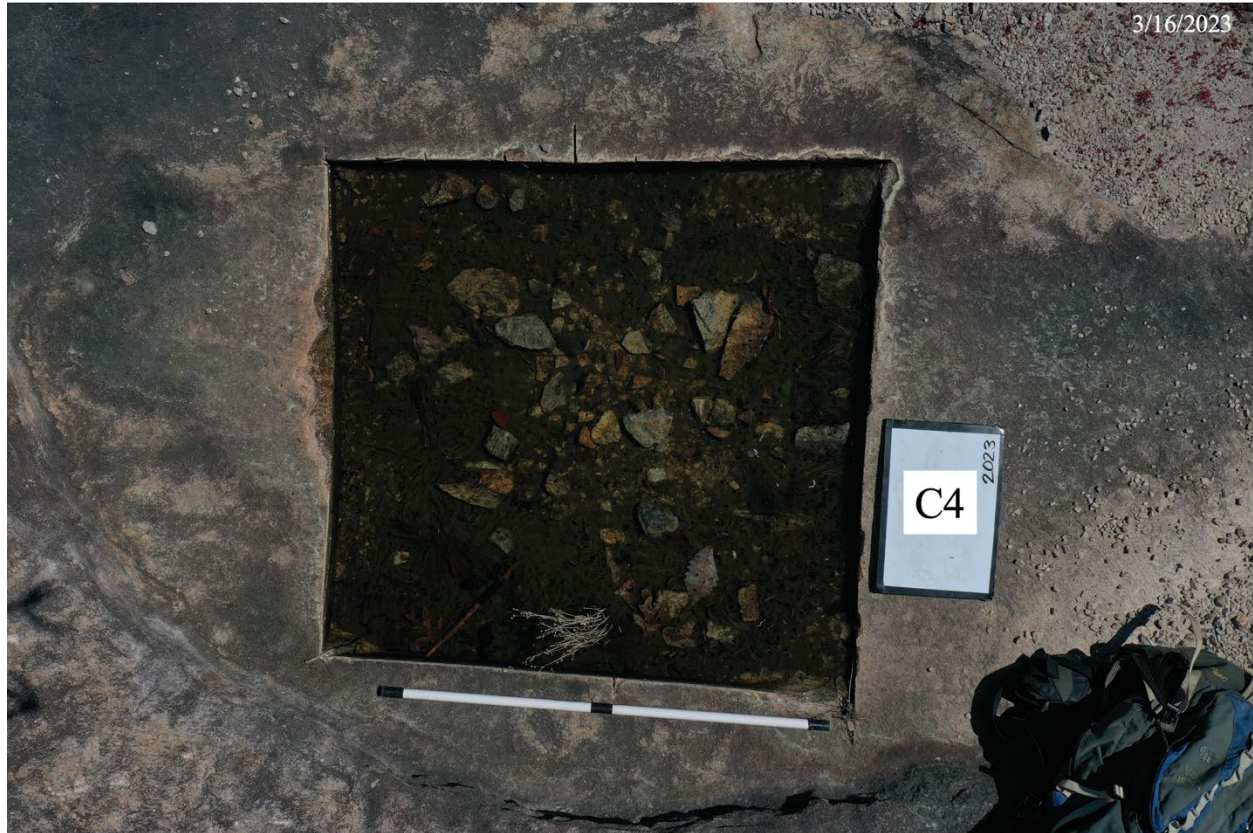
C3, 3/16/2023. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length.

Enhancement: Pool was created de novo from bare rock. Soil and plants were transplanted into the created pool.

Outcome: *Isoetes melanospora* persists in 2023 and appears to be reproducing and/or stabilizing as the percent cover estimate has fluctuated from 30% in 2015 to 40% in 2017. Estimates were 25% and 35% in 2022 and 2023, respectively. The time of survey may influence percent cover estimates as competing vegetation may be present at different points in the season. There were 501-1,000 *Isoetes melanospora* plants in 2023.

Notes: *Gratiola amphiantha* was not found in this pool. Similarly, to C1, there are substantially sized rocks in the pools that if removed, would likely provide more space for the *Isoetes melanospora* to populate. It can be seen from 2022 to 2023 that the rocks are arranged in different ways suggesting human impact on the pool populations. Many of the same comments from C1 apply to C3. *Lindernia monticola*, Piedmont false pimpernel, was present at the time of survey but was not posing a substantial competitive threat.

Phase 1, Site B Pools:

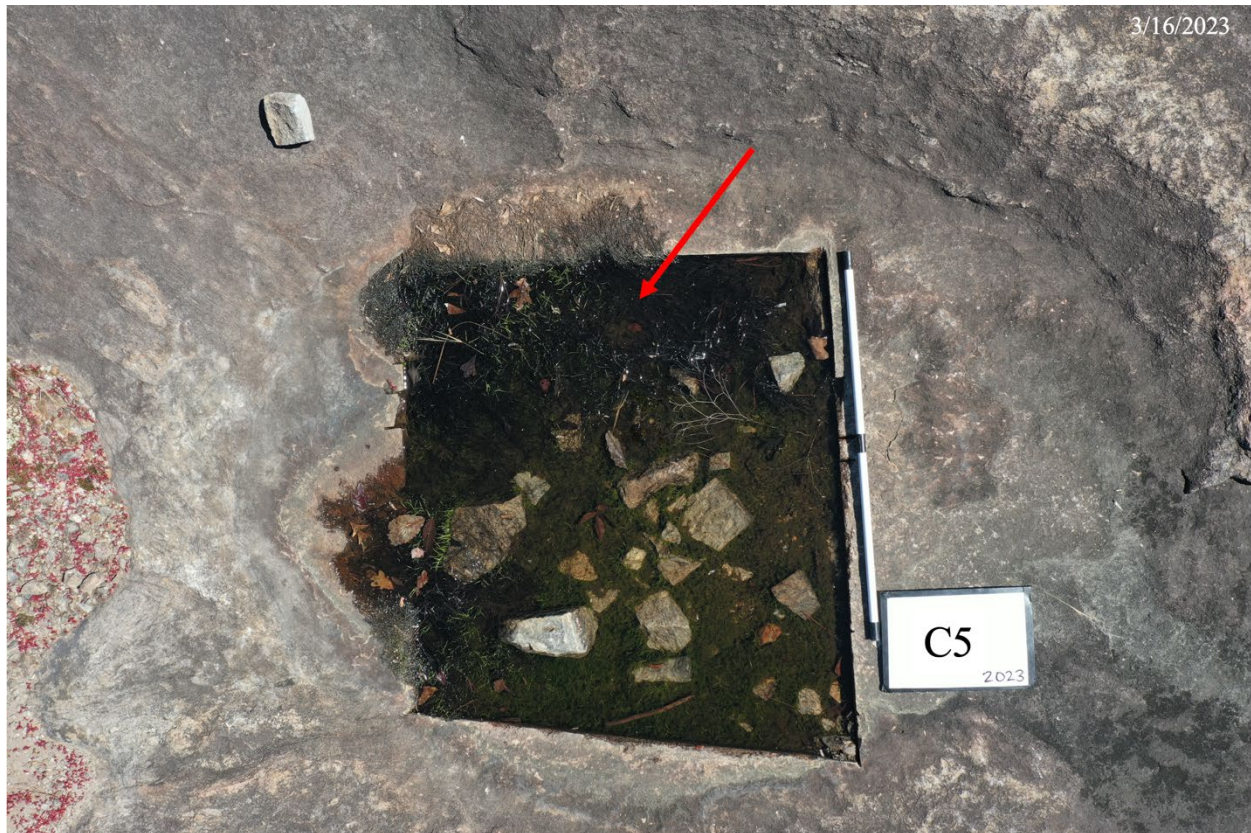


C4, 3/16/2023. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length.

Enhancement: Pool was cut within an existing depression using a diamond blade saw. Soil and plants were transplanted into the created pool.

Outcome: *Isoetes melanospora* persists in 2023 and appears to be stable at less than 5% coverage.

Notes: The careful removal of competing *Juncus* is strongly recommended. Removing the rocks would likely result in more *I. melanospora* growth to fill in the exposed soil if more competitive, fast-growing vegetation was weeded in the first few seasons of rock removal. There are many large rocks in this pool but, unlike the previous pools, there doesn't appear to me much movement of the rocks from 2022 to 2023. This is likely because C4 and C5 are in Site B of Phase 1 which is further removed from public paths and likely receives very little human impact. There is minimal competing vegetation in this pool. Note that C4 has been deepened within an existing pool. The more abundant vegetation seen in the photo is a *Juncus* or other species. There were 51-100 *Isoetes melanospora* plants in 2023. The PVC pipe is one meter.



C5, 3/16/2023. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length.

Enhancement: Pool was cut within an existing depression using a diamond blade saw. Soil and plants were transplanted into the created pool.

Outcome: *Isoetes melanospora* persists in 2022 and appears to be reproducing as the percent cover estimate has increased from 25% in 2015 to 80% in 2023. Weeding of competing vegetation is recommended (red arrow). Removing rocks from the pool is also recommended. There were 1,000-10,000 *Isoetes melanospora* plants in 2023.

Notes: The rocks within this pool are also unmoved from 2022 to 2023. There is a large amount of *Lindernia monticola*, Piedmont false pimpernel, in this pool (red arrow) which could be weeded to provide more habitat for the *I. melanospora* population. The established *I. melanospora* is robust where it grows in this pool. The PVC pipe is one meter.



Figure 30. Site A of Phase 1. Past quarrying has removed top layers of the outcrop, leaving a bare surface with few natural depressions and thus minimal vegetative growth causing shading or debris accumulation in the enhanced pools. Image was taken using a DJI Mavic Pro drone.



Figure 31. Site B of Phase 1 located along the edge of the outcrop. C5 is pictured here, cut within an existing depression.

Phase 2 Pools:



C6, 2/16/2023. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length.

Enhancement: Pool was created de novo from bare rock. Soil and plants were transplanted into the created pool. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length.

Outcome: *Isoetes melanospora* persists in 2023 at 20% coverage and *Gratiola amphiantha* at less than 5% coverage. This pool is successful and could be enhanced further by removing the many rocks present. There were 1,000-10,000 *Isoetes melanospora* plants present in 2023.

Notes: No other competing plant species were present at the time of survey. The PVC pipe is one meter.



C7, 2/16/2023 and 5/19/2022. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length. Top image shows the pool with water and growing plants. The red arrow points in the direction of the soil gradient which is deepest to the left. The bottom image shows a dry pool that more clearly shows the gradient in soil depth.

Enhancement: Pool was created de novo from bare rock. Soil and plants were transplanted into the created pool.

Outcome: In 2023 *Isoetes melanospora* covered less than 5% of this pool, likely due to being too shallow. This pool is slanted (variable bottom depth). As evident in the above photos, *Isoetes melanospora* grows only in the deeper (left side) of the pool, which contains more organic matter than the right side of the pool (red arrow points towards deeper side). *Gratiola amphiantha* covered less than 5% of this pool in 2023, as well. There were 51-100 *Isoetes melanospora* plants present in 2023.

Notes: A small amount of *Juncus* or other graminoid species was present in a small amount in the corner of the pool but doesn't pose a substantial threat to the population at this point.



C8, 2/16/2023. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length.

Enhancement: Pool was created de novo from bare rock. Soil and plants were transplanted into the created pool.

Outcome: In 2023, *Isoetes melanospora* covered 15% of the pool while *Gratiola amphiantha* covered 5%. The establishment of this pool has been successful, and the populations could be further enhanced by removing the rocks present. There were 100-500 *Isoetes melanospora* plants present in 2023.



C9, 2/16/2023 and 5/19/2022. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length. Top image shows the pool with water and growing plants. The red arrow points in the direction of the soil gradient which is deepest to the left. The bottom image shows a dry pool that more clearly shows the gradient in soil depth.

Enhancement: Pool was created de novo from bare rock. Soil and plants were transplanted into the created pool.

Outcome: Similarly, to C7, C9 is slanted (variable bottom depth) with *Isoetes melanospora* only growing in the deeper, left side of the pool, covering less than 5% of the pool. This pool is slanted (variable bottom depth). As evident in the above photos, *Isoetes melanospora* grows only in the deeper (left side) of the pool, which contains more organic matter than the right side of the pool (red arrow points towards deeper side). *Gratiola amphiantha* was more abundant in this pool, covering 5% of the pool. The variable depth of this pool is likely limiting the *I. melanospora* populations and favoring the *G. amphiantha*. There were 51-100 *Isoetes melanospora* plants present in 2023.





C10, 2/16/2023 and 5/19/2022. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length. Top image shows the pool with water and growing plants. The red arrow points in the direction of the soil gradient which is deepest to the right. The bottom image shows a dry pool that more clearly shows the gradient in soil depth.

Enhancement: Pool was created de novo from bare rock. Soil and plants were transplanted into the created pool.

Outcome: *Isoetes melanospora* covered less than 5% of the pool in 2023, with *G. amphianhta* covering 15% of the pool. This pool is slanted (variable depth). As evident in the above photos, *Isoetes melanospora* grows only in the deeper (bottom right side) of the pool, which contains more organic matter than the right side of the pool (red arrow points towards deeper side). Consistent soil depths would further enhance the *I. melanospora* population. There were 11-50 *I. melanospora* plants present in 2023.

Greensboro South, Greene County

Summary of Success at Greensboro South:

The enhancement efforts at Greensboro South have been overall successful, with some populations establishing more robustly than others (Fig. 32). The main threat to the persistence of the introduced species seems to be competing vegetation. Pool 1 supports only a small *I. tegetiformans* population likely due to the competition from other vegetation. Pool 2, Pool 3, and Kyla's pool have the most robust *I. tegetiformans* density, covering most of the deepened portion of the pool. Pete's Pool, Pool 4, and Pool 5 were deepened using only with a steel rod and have more shallow depressions than the more successfully enhanced pools.

On April 28, 2022, Anna Wyngaarden, Mincy Moffett, and Pete Pattavina visited Greensboro South to survey, map, and photograph the enhanced pools. Pools were mapped with the GPS unit and percent cover estimates of the species were recorded. At the time of survey (late in the season), some of the *I. tegetiformans* pools were completely dry, with plants senescing in the drought. The drone was being repaired at the time of survey, thus photos were taken with an iPhone. Returning on February 28, 2023, Anna Wyngaarden and Riley Thoen (UGA) surveyed and photographed the populations using the repaired drone.

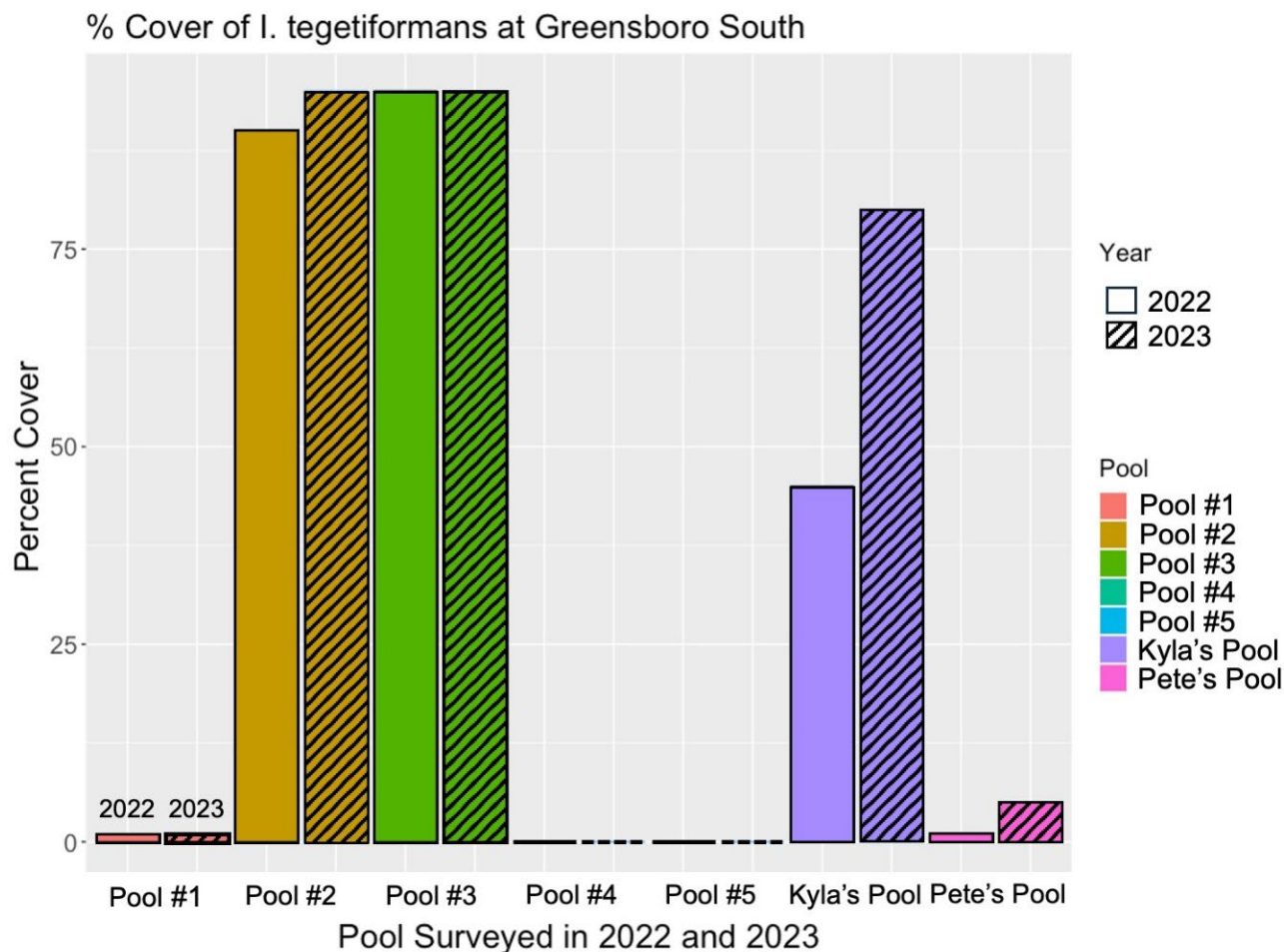
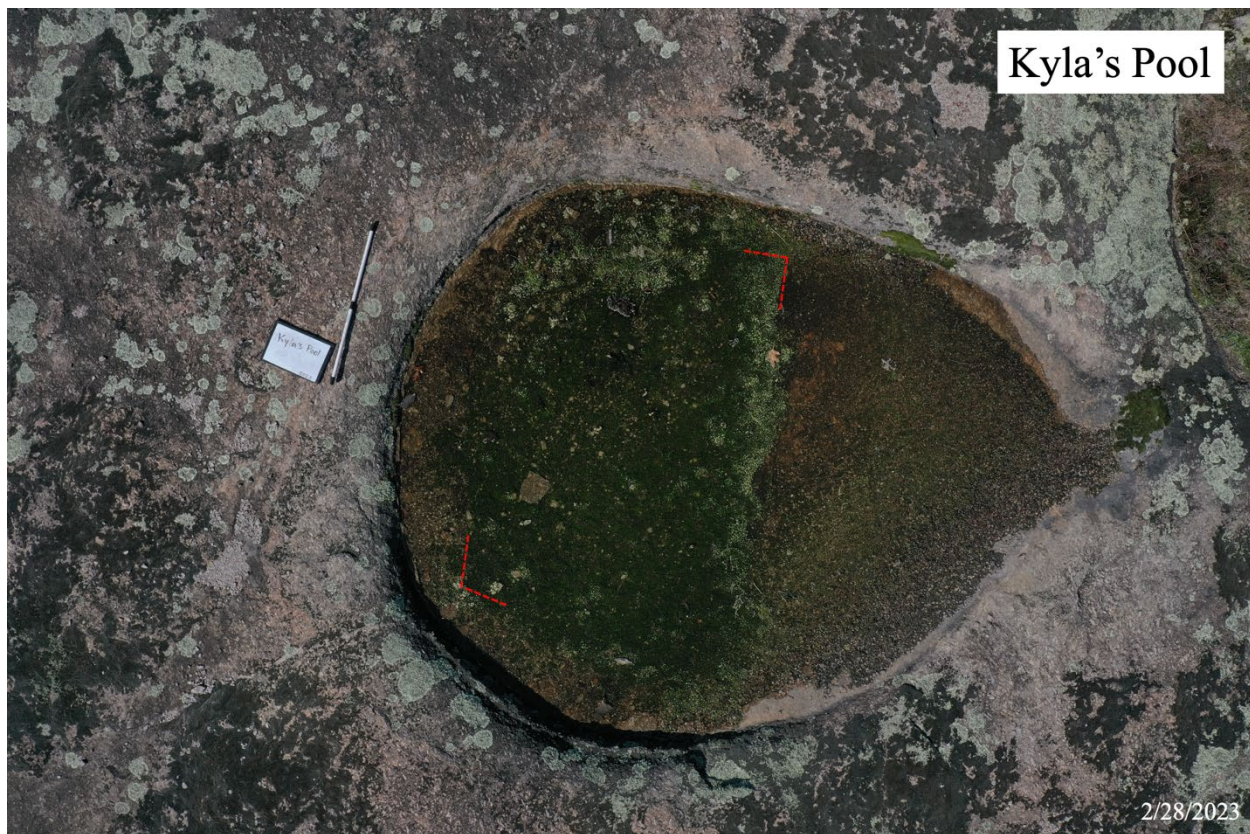


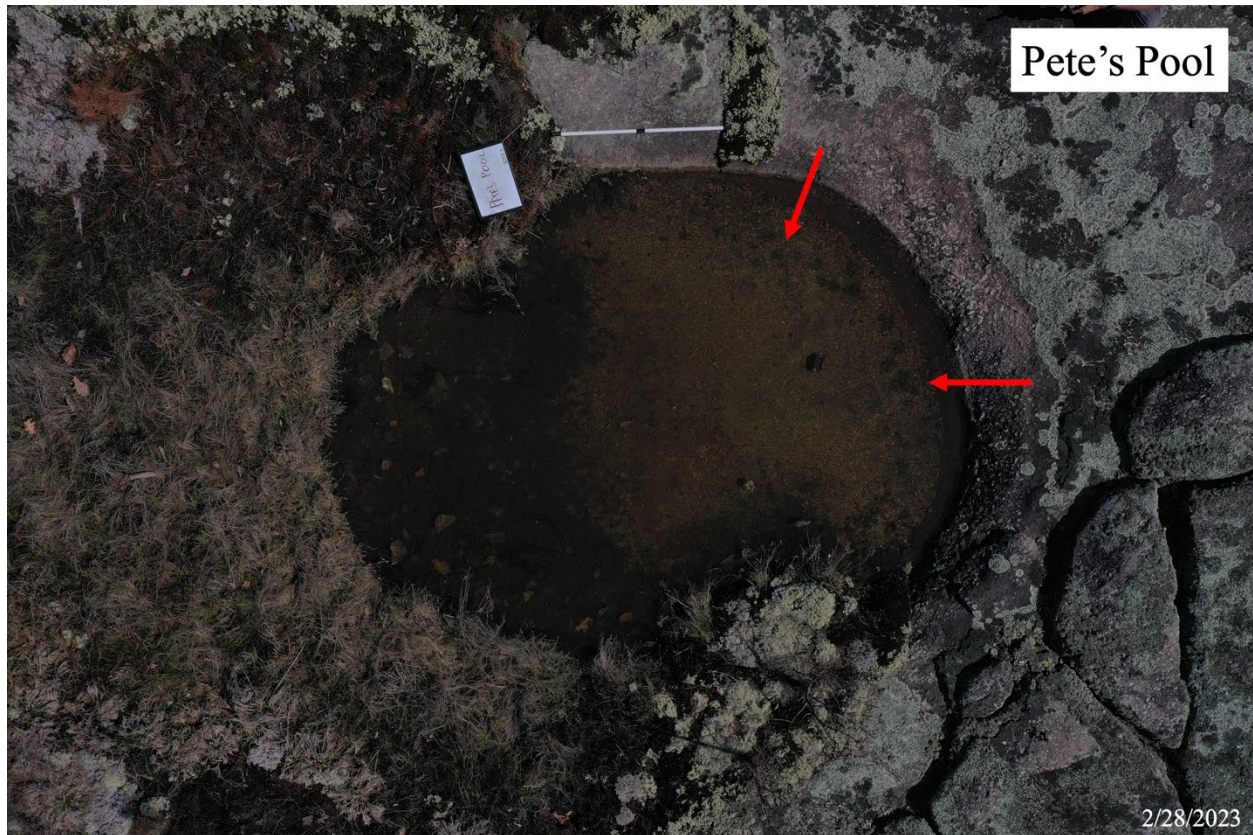
Figure 32. Percent cover estimates of *I. tegetiformans* populations at Greensboro South in 2022 (solid color) and 2023 (hatched line fill). Percent cover data do not exist for these pools prior to 2022. The increased percent cover seen in both Kyla’s and Pete’s pool from 2022 to 2023 is likely due to the time of survey as surveys were done late in the season in 2022. Pool 4 and 5 do not support any *I. tegetiformans*. *Gratiola amphantha* has not been observed in the enhanced pools at Greensboro South. Future surveys are encouraged to continue monitoring population growth or decline. These data are available in Table 3. In-field measurements of “<5%” are entered as 1% here.



Kyla’s Pool, 2/28/2023. Red lines indicate the corners of the deepened portion within the existing depression. The white, vertically oriented PVC pipe in the photo, placed for scale, is one (1) meter in length.

Enhancement: This pool was the first one enhanced at Greensboro South. Native soil was removed from the pool and it was deepened with a jackhammer, removing the upper ~2 inches of granite in 2012. Soil was replaced into the pool after being collected from nearby pools and sterilized in a metal trashcan using a barbecue grill. *Isoetes tegetiformans* was transplanted into the pool in 2013 after being collected by a natural pool and propagated at the State Botanical Garden in 2012.

Outcome: The deepened portion of this pool is robust with *I. tegetiformans*, with 95% of the enhanced portion covered by the species and is a strong success.



Pete's Pool, 2/28/2023. The white, horizontally oriented PVC pipe in the photo, placed for scale, is one (1) meter in length. Red arrows point to clumps of existing *I. tegetiformans*.

Enhancement: The pool was manually fractured with a steel rod in 2012 by driving the rod into the rock by hand, removing minimal fractures of granite. *Isoetes tegetiformans* was then transplanted into the pool in 2013 but did not initially persist. Small ramets of *I. tegetiformans* were transplanted into the pool as second time in 2017 and continue to persist.

Outcome: Some *I. tegetiformans* persists in this pool but minimal recruitment has occurred. This pool would likely benefit from deepening with a diamond blade saw in a similar manor as the other pools on site.





Pool 1, 2/28/2023. The white, vertically oriented PVC pipe in the top photo, placed for scale, is one (1) meter in length. Red lines indicate corners of deepened portion of the pool.

Enhancement: This pool was cut within an existing depression using a diamond blade saw in 2015 and *Isoetes tegetiformans* was transplanted in 2016.

Outcome: *Isoetes tegetiformans* has established and persists but only minimally, covering less than 5% of the pool. Removal of competing vegetation may enhance the population. Soil depth and is consistent throughout the pool and it holds water evenly.

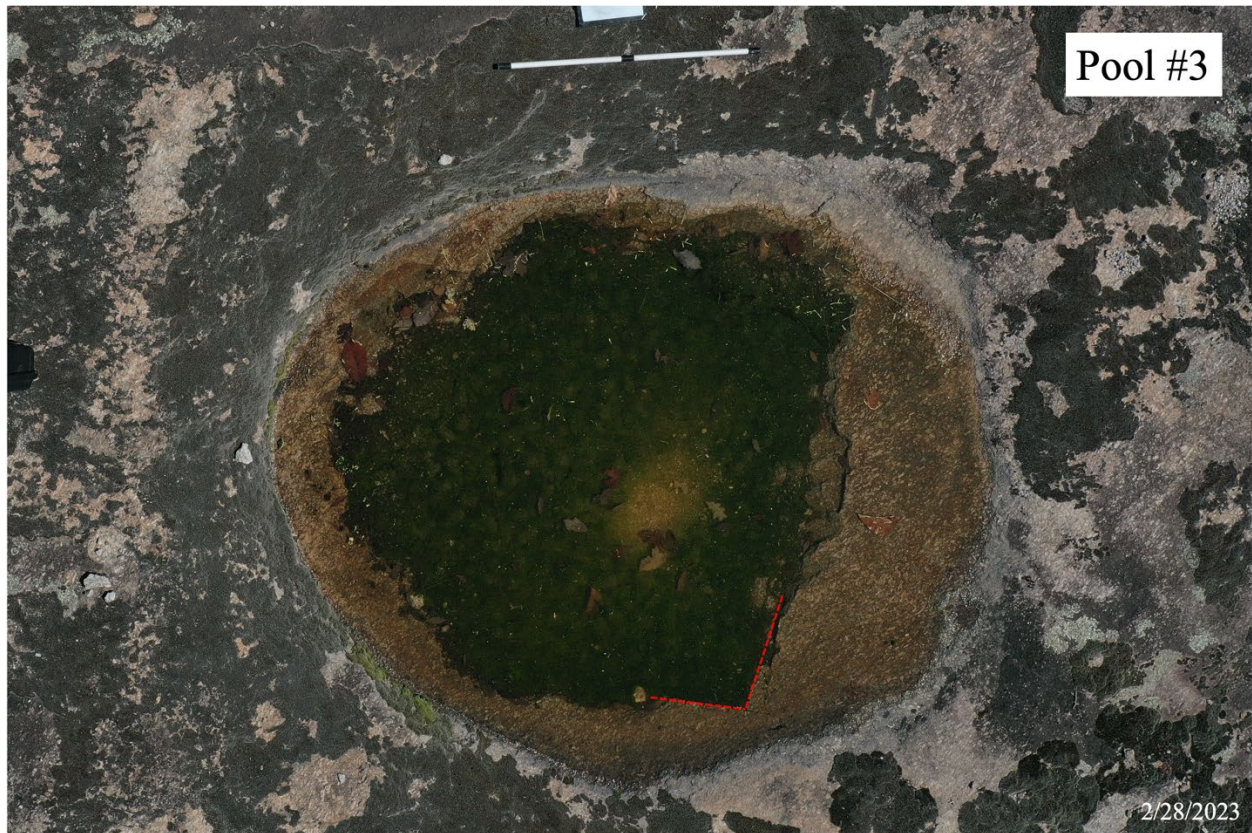
Notes: Much of the visible green in the image is different species (including *Elatine brachysperma* [shortseed waterwort]) not *I. tegetiformans* which is confined to the red circle in the image. The third photo shows the small patch of *I. tegetiformans*.



Pool 2, 2/28/2023. The white PVC pipe in the photo, placed for scale, is one (1) meter in length. Red lines indicate corners of deepened portion of the pool.

Enhancement: This pool was cut within an existing depression using a diamond blade saw in 2015 and *Isoetes tegetiformans* was transplanted in 2016.

Outcome: This pool has a well-established, robust population of *I. tegetiformans*, covering an estimated 95% of the pool in 2023. Similarly, to the enhanced pools at Heggie's Rock, some bare patches of soil exist in the pool, but *I. tegetiformans* has covered most of the available space.



Pool 3, 2/28/2023. The white PVC pipe in the photo, placed for scale, is one (1) meter in length. Red lines indicate corners of deepened portion of the pool.

Enhancement: This pool was cut within an existing depression using a diamond blade saw in 2015 and *Isoetes tegetiformans* was transplanted in 2016.

Outcome: This pool has a well-established, robust population of *I. tegetiformans*, covering an estimated 95% of the pool in 2023. Similarly, to the enhanced pools at Heggie's Rock, some bare patches of soil exist in the pool, but *I. tegetiformans* has covered most of the available space.



Pool 4, 2/28/2023. The white PVC pipe in the photo, placed for scale, is one (1) meter in length.

Enhancement: Prior to the USFWS efforts, this pool was attempted to be deepened by hand using a steel rod in 2013. Deepening was unsuccessful, only removing a thin layer of granite. *Isoetes tegetiformans* was transplanted into this pool at the time, but it failed to establish. In 2017 roughly 40 ramets of *I. tegetiformans* were transplanted into the pool, again, from the trays being used to repopulate Pools 1-3.

Outcome: This was an unsuccessful deepening and transplant as no *I. tegetiformans* was found in this pool in 2022 nor in 2023. The pool is likely too shallow to support the species and there's minimal soil. This pool remains a good candidate for deepening with diamond blade saws and jackhammers as it holds water reliably but is difficult to access with large equipment.



Pool 5, 2/28/2023. Red arrows point to areas shattered with the steel rod. The white PVC pipe in the photo, placed for scale, is one (1) meter in length.

Enhancement: A steel rod was used to shatter the top layer of granite from the pool by hand in 2012. No large equipment was used to deepen this pool. No species were transplanted into this pool.

Outcome: This was unsuccessful because the pool couldn't be deepened more than removing the top layer of granite. No transplants were added to this pool.

Heggie's Rock, Columbia County
Summary of Success at Heggie's Rock:

All of the enhanced pools at Heggie's Rock have been successfully established with *I. tegetiformans*, *G. amphiantha*, or both, in each (Fig. 33; Fig. 34). While one pool was not deemed suitable for *I. tegetiformans* transplants at the time of creation, the *G. amphiantha* that was transplanted in its place has established well. The *I. tegetiformans* populations in other pools have grown to mimic the type locality pool located at the top of Heggie's Rock – covering almost the entirety of the pool. This project has shown that when provided with the proper depth of soil and water *I. tegetiformans* can persist with minimal, if any, continued intervention.

On March 26, 2022, Anna Wyngaarden surveyed, mapped, and photographed the enhanced pools at Heggie's Rock. Pools were saturated with water at the time of survey. On February 14, 2023, Anna Wyngaarden, Mincy Moffett, and Malcolm Hodges returned to Heggie's Rock to survey and photograph the enhanced pools, as well as to explore the entirety of the outcrop. Pools were robust and filled with water at the time of survey in 2023.

While not part of the enhancement project directly, a natural pool near East Pool was found with a clump of *Isoetes tegetiformans* in it. Hodges had never seen the species in this pool prior to this date and there was too much plant material to have grown since his last visit to the rock. To all, it seemed a clump of the *I. tegetiformans* had been removed from the nearby East Pool either by an animal, wind, or some other unexplained event, including an unauthorized human "Johnny-Appleseed" event. This stochastic example of pool colonization by *I. tegetiformans* is intriguing and few examples such as this exist. The tenacity, and potential of the species to persist seems limited largely by habitat availability, further validating the success of, and need for, these enhancement efforts.

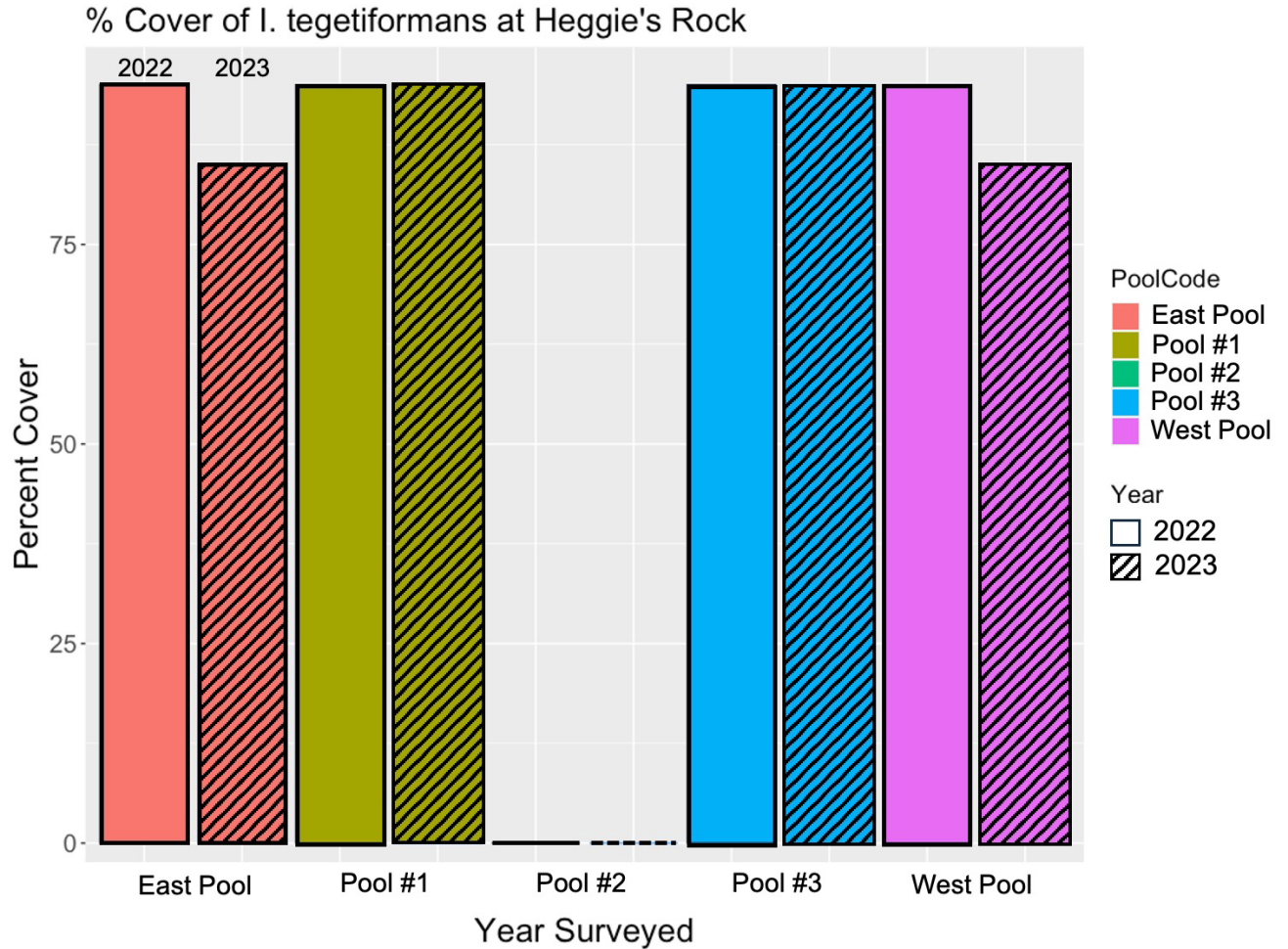


Figure 33. Percent cover estimates of *Isoetes tegetiformans* at Heggie’s Rock in 2022 (solid color) and 2023 (hatched line fill). Pool 2 never received *I. tegetiformans* transplants because it failed to hold enough water. It was seeded with nearby *G. amphiantha*, see Figure 34. Differences in percent cover measurements from 2022 to 2023 may be due to the timing of survey from year to year. Percent cover data do not exist prior to 2022. Future surveys are encouraged to continue monitoring population growth or decline. These data are available in Table 3.

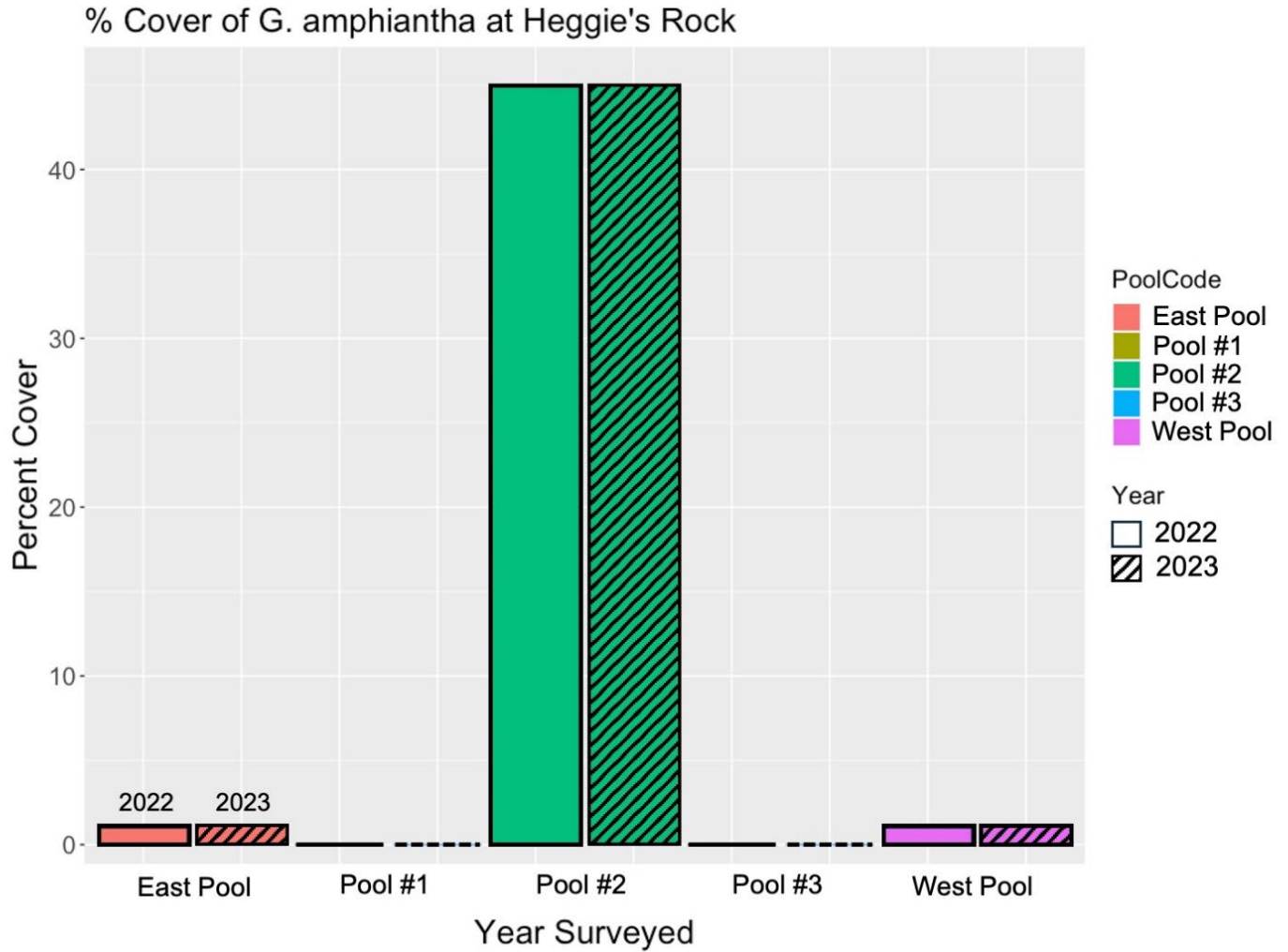


Figure 34. Percent cover estimates of *G. amphiantha* at Heggie’s Rock in 2022 (solid color) and 2023 (hatched line fill). Pool 2 is the only pool to directly receive *G. amphiantha* transplants, but the species is naturally present in pools surrounding all enhanced sites. These data are available in Table 3. In-field measurements of “<5%” are entered as 1% here.



Pool #1, 2/13/2023. The white PVC pipe in the photo, placed for scale, is one (1) meter in length.

Enhancement: This pool was cut within an existing depression in 2016 and *Isoetes tegetiformans* was transplanted in 2017.

Outcome: This pool has been extremely successful, covering an estimated 95% of the pool. There are small portions of the enhanced pool that are not filled with *Isoetes tegetiformans*. The species has continued to grow beyond the pool, in cracks and shallow depressions along the rim of the pool.



Pool #2, 2/13/2023. The white PVC pipe in the photo, placed for scale, is one (1) meter in length.

Enhancement: This pool was cut within an existing depression in 2016 and *G. amphiantha* was introduced after it was found to have a leak in 2017.

Outcome: This pool is successful. While not populated with *I. tegetiformans*, successfully supports *Gratiola amphiantha* at an estimated 45% cover in 2023.

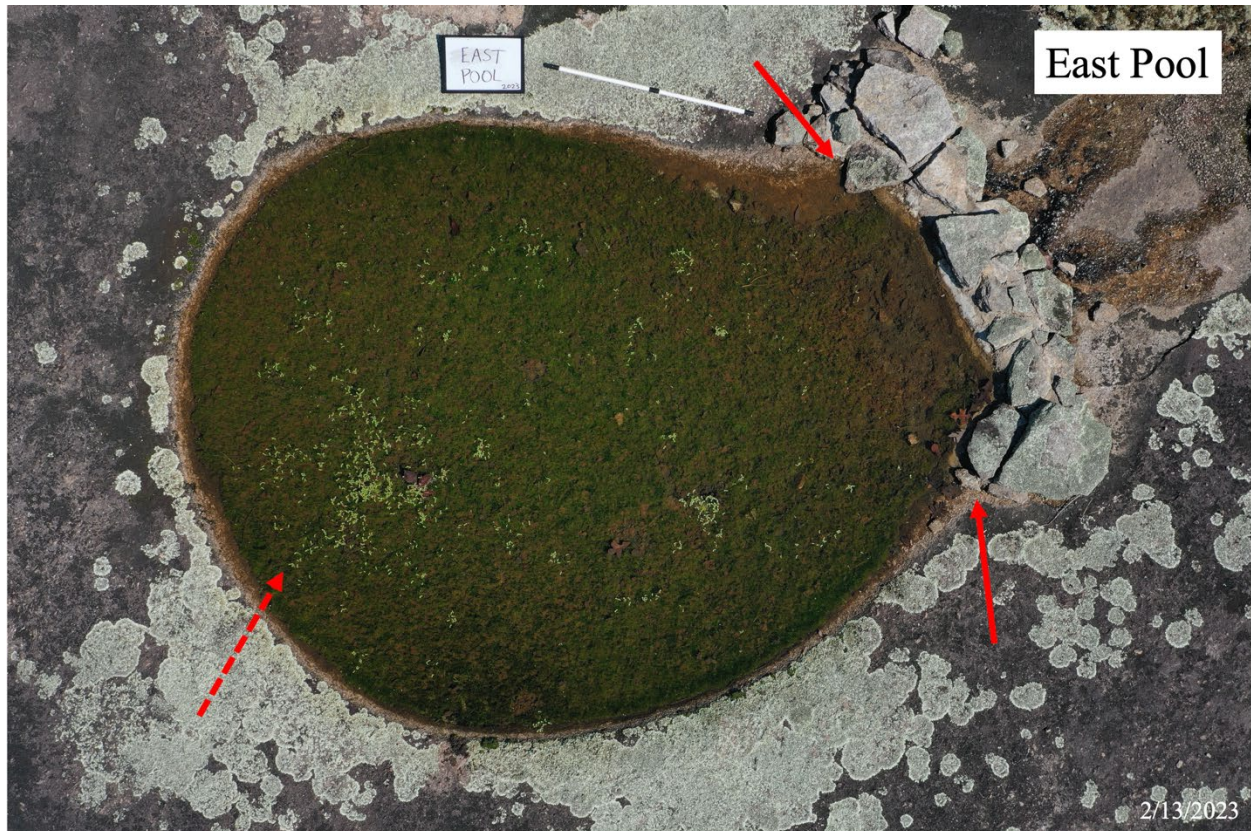
Notes: It's important to notice that Pool #2 is situated between Pool #1 and #3 and is exposed to the same levels of precipitation and solar exposure (Fig. 19). In 2022 it's seen here dry, while both Pool #1 and #3 are saturated at the same time. This indicates that Pool #2 likely has a leak and, thus, would not likely support *I. tegetiformans*, although an attempt would be warranted. The soil depth is the same as Pool #1 and #3 and the pool can hold water, but with less longevity than the others.



Pool #3, 2/13/2023. The white PVC pipe in the photo, placed for scale, is one (1) meter in length. The yellow on the surface in 2022 is pollen.

Enhancement: This pool was cut within an existing depression in 2016 and *Isoetes tegetiformans* was transplanted in 2017.

Outcome: This pool has been extremely successful, with the species covering an estimated 95% of the pool. There are small portions of the enhanced pool that are not filled with *Isoetes tegetiformans*.

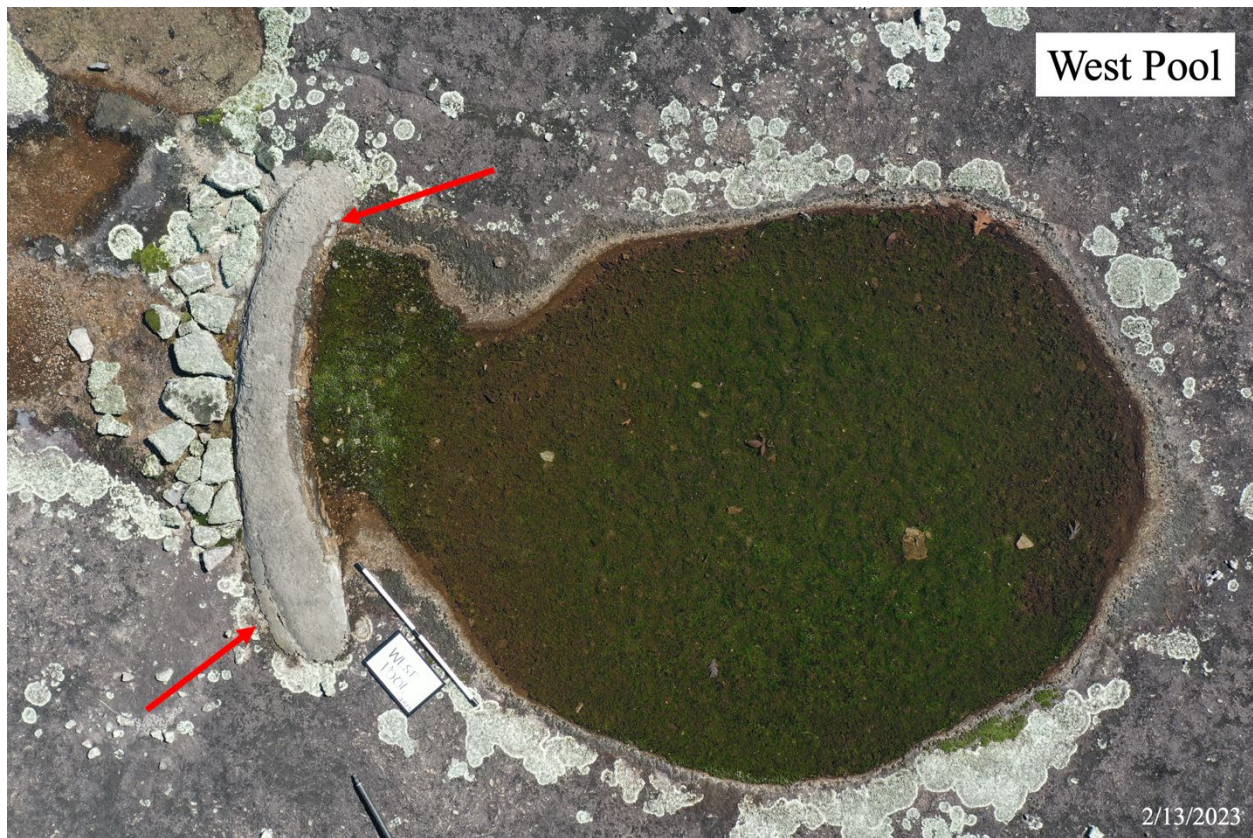


East Pool, 2/13/2023. The white PVC pipe in the photo, placed for scale, is one (1) meter in length. Dotted red arrow is pointing to *G. amphiantha* and solid arrows are pointing to concrete dam.

Enhancement: This pool was populated with *Isoetes tegetiformans* from Mt. Gemini in the 1980s and a concrete dam was added to stop the flow of water out of the pool circa 1988. Spare rocks have been piled atop the concrete dam to help reinforce it (solid red arrows).

Outcome: This population of *Isoetes tegetiformans* is robust and successful, covering an estimated 85% of the pool in 2023. *Gratiola amphiantha* also persists in this pool, covering less than 5% of the pool. This pool is surrounded by naturally populated *G. amphiantha* pools.

Notes: *Isoetes piedmontana* is present in this pool in a small clump on the southern side of the pool. The species is abundant throughout the outcrop. The lighter green on the surface of the water in 2023 is *G. amphiantha* and it's likely that because it was later in the season in 2022 at the time of survey, *G. amphiantha* was not as robust or visible in 2022.



West Pool, 2/13/2023. The white PVC pipe in the photo, placed for scale, is one (1) meter in length. Red arrows point to the concrete dam stopping the flow of water out of the pool.

Enhancement: This pool was populated with *I. tegetiformans* from Mt. Gemini in the 1980s and a concrete dam was added circa 1988 (red arrows). The concrete dam has been repaired minimally throughout the years.

Outcome: This population of *Isoetes tegetiformans* is robust and successful, covering an estimated 95% of the pool in 2023. *Gratiola amphiantha* also persists in this pool covering less than 5% of the pool, only occurring in the center of the pool. This pool is surrounded by naturally populated *G. amphiantha* pools.

Notes: *Isoetes piedmontana* is present in this pool as well, covering less than 5% of the pool.

Conclusions and Recommendations

The complete creation of new habitat for *Isoetes melanospora*, *Isoetes tegetiformans*, and *Gratiola amphiantha* has been shown to be successful. This report has recounted a myriad of ways that the species' habitat has been enhanced, utilizing various levels of effort and funding. While varying in their levels of abundance and degree of establishment, deepening pools, and creating entirely new habitat for the species has been proven successful.

When choosing to create or deepen pools, several guidelines have been developed over the years that should be considered. First, pools, should be located at the top of the watershed on a granite outcrop. Existing depressions should be free of any obvious leaks, and any that sound "hollow" when tapped with a steel rod or tool should be excluded from consideration. They likely have pockets of air beneath them and/or are connected to cracks between exfoliating layers of rock. Even if they currently hold water, they are more likely to crack and leak in the future.

Additionally, the most successful efforts are those that have deepened existing depressions and transplanted source material into them. *Isoetes* tended to do better at establishing in pools that were deepened in existing depressions compared to being created de novo from bare rock. This may be because natural depressions are predisposed to hold more water. However, this difference also corresponds to the fact that *Isoetes tegetiformans* has been transplanted only into the deepened pools and *Isoetes melanospora* has been transplanted only into the de novo cut pools. This disparate treatment was unintentional and reflects the organic evolution and development of pool enhancement conservation. Since *Isoetes tegetiformans* reproduces vegetatively as well as by spores, it is potentially able to spread more readily than *I. melanospora* which reproduces mainly by spores. Therefore, any determination in favor of deepening existing depressions vs. de novo creation may be biased due to reproductive differences of the species. Considering percent cover measurements as an indicator of success will lead to discrepancies when comparing the two species. Nevertheless, both methods are effective. This observed difference would clearly benefit from a formally designed study.

The cost and effort included in these projects were not evaluated in this report but should be considered when planning future projects. While the most effective approaches were de novo creation and deepening of existing pools, these large projects alter the landscape of the site. However, the work at Pete's Pool offers an example of marginal success with low effort, cost, and impact to the rock landscape. This pool was deepened with a steel rod and ramets of *Isoetes tegetiformans* were transplanted, first unsuccessfully, but achieved success with a second out planting. The minor deepening of this pool is not visually detectable today which is a benefit.

For any of the enhancement approaches to be successful, existing pools must be properly chosen based on existing depth, location on the outcrop, and water holding capacity. Additionally, choosing the appropriate source material for reintroductions remains a central topic when transplanting material into created sites.

Lastly, while the efforts in these projects were aimed at creating habitat for *I. melanospora* and *tegetiformans*, *G. amphiantha* often benefitted as well. As practiced in Pool #2 at Heggie's Rock, pools that may not be fully suitable for either *Isoetes* species will likely still be suitable for *G. amphiantha*.

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