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Use of Prescribed Fire to Increase Detectability of Gopher Tortoise (*Gopherus polyphemus*) Burrows Prior to Relocation

Lance Paden[1,4], Kimberly M. Andrews[1,2], Carmen Candal[2], and James F. Renner[3]

[1]*Odum School of Ecology, University of Georgia, Athens, Georgia 30602, USA*
[2]*University of Georgia, Savannah River Ecology Laboratory, Aiken, South Carolina 29802, USA*
[3]*Southern Ionics Minerals LLC, 116 Hamilton St., Saint Simons Island, Georgia 31522, USA*
[4]*Corresponding author, e-mail: lance.paden89@gmail.com*

Abstract.—**Relocation of Gopher Tortoise (*Gopherus polyphemus*) populations is a commonly used impact mitigation strategy where their presence conflicts with anthropogenic development. Proper detection of burrows is crucial for detecting both tortoises and priority commensal species, such as Eastern Indigo Snakes (*Drymarchon couperi*), Florida Pine Snakes (*Pituophis melanoleucus mugitus*), and Gopher Frogs (*Lithobates capito*), which use *G. polyphemus* and Nine-banded Armadillo (*Dasypus novemcinctus*) burrows. So as not to leave behind any tortoises requiring mitigation action, we tried survey approaches to increase detectability of all *G. polyphemus* and *D. novemcinctus* burrows, especially those of juvenile *G. polyphemus* in dense vegetation. In summer and fall 2016, we conducted burrow surveys across about 16 ha of sandhill-Longleaf Pine (*Pinus palustris*) habitat. Initial surveys revealed high densities of hatchling and juvenile *G. polyphemus*. Therefore, we conducted a prescribed burn to clear out dense herbaceous groundcover that hides small tortoise burrows, thereby increasing burrow detectability. We compared pre- and post-burn survey results along with a detailed explanation of our survey methods. We located 323 *G. polyphemus* and *D. novemcinctus* burrows prior to the burn and an additional 91 burrows post-burn. Approximately 28% of burrows were detected post-burn. Many burrows and *G. polyphemus* were initially missed due to vegetation overgrowth hindering detection. Prescribed fire increased our survey efficiency and accuracy, resulting in a more comprehensive extraction and translocation of animals. We therefore recommend that prescribed fires be used to increase survey effectiveness for *G. polyphemus* and other sandhills co-habitants where resource provisions and regulatory restrictions permit it.**

Key Words.—armadillo; commensal; detection; Georgia; longleaf; reptile; sandhills; survey

Introduction

The Gopher Tortoise (*Gopherus polyphemus*) is considered a keystone species of the southeastern USA coastal plain as it creates extensive burrows and microhabitat that provide shelter for a diversity of organisms (Witz et al. 1991; Catano and Stout 2015; White and Tuberville 2017). In Georgia, *G. polyphemus* is currently state listed as threatened and is under review for federal listing as an endangered species through the U.S. Endangered Species Act administered by the U.S. Fish and Wildlife Service (USFWS). Several additional state and federally listed imperiled commensal species of *G. polyphemus* are also of particular interest in Georgia. Such species include Eastern Indigo Snakes (*Drymarchon couperi*), Gopher Frogs (*Lithobates capito*), Florida Pine Snakes (*Pituophis melanoleucus mugitus*), and Southern Hognose Snakes (*Heterodon simus*; Jensen et al. 2008), and even more species have been petitioned for federal listing (e.g., the Eastern Diamondback Rattlesnake, *Crotalus adamanteus*; USFWS 2012).

Much of the xeric upland habitat throughout the range of *G. polyphemus*, particularly sandhill and Longleaf Pine (*Pinus palustris*) ecosystems, has been destroyed either due to habitat fragmentation, development, or has been otherwise altered for human use (Diemer 1986; Landers et al. 1995; Smith et al. 2015). It is estimated that only 1% of the original extent of the Longleaf Pine ecosystem remains, making it one of the most endangered habitats on the planet (Noss 2012). Therefore, relocation of *G. polyphemus* has become pervasive as a means of mitigation of these human impacts on their populations (Burke 1989). This project focused on areas that will be developed by mining operations. The Nongame Division of the Georgia Department of Natural Resources (GADNR) requires that all tortoises be relocated from areas impacted by this development to suitable Wildlife Management Area (WMA) recipient sites. We also relocated any vertebrate commensal species found during our surveys to the nearest suitable habitat outside of the mine impact area.

To perform these relocations, we searched all active and inactive *G. polyphemus* burrows and other possible

G. polyphemus and commensal refugia sites, such as Nine-Banded Armadillo (*Dasypus novemcinctus*) burrows, to maximize detectability of all target and co-occurring species. *Dasypus novemcinctus* is a wide-ranging species that has dramatically expanded the northern extent of its range into the U.S. in the past 170 y from Mexico (Taulman and Robbins 1996). Hatchling and juvenile *G. polyphemus*, in particular, tend to select secretive sites tucked under vegetation where they can be hidden and protected from exposure to hot and dry conditions. Hence, detecting all *G. polyphemus* and *D. novemcinctus* burrows is time consuming and difficult, if not impossible, in habitats with dense vegetation and ground cover, resulting in burrow censuses that are unreliable despite being conducted by experienced surveyors. Unreliable burrow census surveys prior to land clearing and development can result in unnecessarily high incidental mortality. As such, several techniques have been developed by various researchers to attempt to accurately sample *G. polyphemus* burrows (Carthy et al. 2005; Nomani et al. 2008). An abundance of juvenile and hatchling *G. polyphemus* burrows in dense herbaceous groundcover at this study site necessitated an efficient detection method.

Prescribed fire is a common management tool in ecosystems naturally inhabited by *G. polyphemus* to maintain desirable vegetation (Diemer 1986; Yager et al. 2007). Therefore, prior to completing a relocation in the summer and fall 2016, we conducted a controlled burn to improve ground visibility and increase burrow detectability. Growing season burns have not been documented to do harm to *G. polyphemus* populations, which readily shelter in their burrows and rely on fires to replenish their herbaceous forage (e.g., Carr 1952). Additionally, they have evolved in systems that experience frequent, low-intensity fires that are typical of *P. palustris* ecosystems in the southeastern US (Robbins and Myers 1992) and growing season fires in particular have been used to manage habitat for *G. polyphemus* throughout their range (Guyer, Johnson, and Hermann 2012).

Our management objective was to maximize burrow detectability by creating a clear line of sight to the ground. We hypothesized that increased visibility could allow for greater detection of burrows that otherwise are obscured easily by vegetation. After burning, improved burrow detection should likewise result in the translocation of populations consisting of a more representative demographic distribution, rather than younger age classes of *G. polyphemus* being differentially reduced because they are difficult to detect. To determine the effectiveness of prescribed fire at increasing burrow detectability, we conducted comparative pre- and post-burn surveys of the future mine impact area. We predicted that the prescribed burn would improve burrow detection, particularly those of smaller individuals, and therefore result in finding more *G. polyphemus.*

Materials and Methods

***Study site.*—**We conducted this burrow survey and relocation work at the Mission Mine of Southern Ionics located in Charlton County, Georgia, USA, June-October 2016. The study site is about 16 ha of privately owned, xeric upland habitat that has burned on an irregular cycle and was selectively harvested for pine trees (*Pinus* spp.) about 8 y prior to our surveys. Approximately 72% of the site was dominated by a mosaic of American Turkey Oak (*Quercus laevis*), Wire-grass (*Aristida stricta*), gallberry (*Ilex* spp.), Saw Palmetto (*Serenoa repens*), and Slash Pine (*Pinus elliottii*). The remaining approximately 28% of the site was a modified pasture and lawn with a house and several small buildings. Depth to water table across the site was generally about 1.5–3.0 m below the surface as observed during burrow excavations.

***Burrow surveys.*—**For initial surveys, we performed line transect burrow surveys on foot throughout the site, navigating using a GPS device (GPSmap 64s, Garmin International Inc., Olathe, Kansas, USA). We identified *G. polyphemus* burrows by their bare sand apron (burrow spoil mound) and crescent-shaped entrance. Inactive *G. polyphemus* burrows as well as active and inactive *D. novemcinctus* burrows were typically less obvious and often hidden by understory vegetation or leaf litter. We classified burrow activity based solely on the presence of external burrow characteristics such as tracks and fresh digging. Because our goal was to find and relocate all *G. polyphemus* and vertebrate commensals from the impact area, we surveyed using methods to ensure 100% coverage of the survey plots, which were repeated until no new detections occurred.

We performed surveys with 2–4 surveyors walking approximately 5–10 m apart in unison along one direction across the site. We attempted to maintain each transect pass at a width less than our estimated line-of-sight to burrows within each particular microhabitat (as influenced by visibility that varied with vegetation density) to allow for the greatest coverage while maximizing the likelihood of burrow detection. One person was designated as the lead surveyor and carried the GPS with Tracks enabled to navigate from, and adjust accordingly, throughout the survey to achieve greatest coverage and avoid missing areas. Other surveyors adjusted their path corresponding to the route of the lead surveyor. We conducted transect in both North-South and East-West orientations across the site to aid in detection. Where visibility was limited due to vegetation, we used a snake hook to pull back the vegetation edges in promising areas that are typical of juvenile burrow placement (i.e., under *A. stricta* clumps and *S. repens* fronds). It was not our objective in this aspect of the study to quantify how different species of vegetation influence detectability, although that inquiry would be novel and valuable for understanding detectability of *G. polyphemus* and management of their habitat.

Once we located a burrow, we collected a GPS waypoint, and placed orange flagging tape on the closest tree or shrub at eye-level. We labeled burrow flags using a marker pen with the date found, waypoint number, burrow size class, externally apparent activity, and occupancy (once burrow was scoped, see below). If we did not locate a burrow in an obvious position, as is typically the case with hatchling and juvenile burrows, we placed flagging on the nearest tree branch in the direction of the burrow to aid in quickly re-finding the burrow. We used a burrow camera system custom-made by Emmett Blankenship, DVM (Environmental Management Systems, Canton, Georgia, USA) of all burrows we found on the site (burrow-scoping). We conducted burrow-scoping surveys in the shortest possible time period (typically all were scoped within 1 d in a given region of the site, such as burn units) to limit the possibility of *G. polyphemus* movement skewing occupancy estimates of the population.

We surveyed the study site multiple times such that transects were staggered and the entire site was covered thoroughly. We repeated surveys until no new burrows were found anywhere within the site on each pass, which lends support for the assumption that we were detecting all burrows within a survey unit. This strategy attempts to inherently account for limitations in burrow detectability across landscapes with highly variable vegetation densities and variable survey effort. Survey duration varied widely based on a variety of logistical field factors, such as surveyor experience and endurance, pausing for burrow-scoping, and burrow excavations occurring concurrently with surveys when necessary. Therefore, we could not reliably estimate overall survey time for the duration of this relocation event; however, this would be valuable to record in instances where the objective is to quantify human effort invested.

Burrow excavations.—We began excavations of occupied burrows 30 August 2016, collapsing unoccupied burrows as we worked through the burrows to prevent re-inhabitation by tortoises or commensal species. To prevent accidently hitting a tortoise with a shovel or excavator bucket, we inserted a polyvinyl chloride (PVC) pipe (about 2 m length, either 1.27 cm or 1.91 cm diameter) into each burrow before digging into it. We continually adjusted the PVC pipe as we dug farther into the burrow until reaching the terminal chamber and removing the tortoise or commensal species found within. We excavated juvenile and hatchling tortoise burrows prior to sub-adult and adult burrows to minimize the chances of accidentally collapsing undiscovered small burrows with the mini-excavator (Caterpillar® 303.5E Mini Hydraulic Excavator, Caterpillar Inc., Griffin, Georgia, USA). We used a shortest-distance route and a burrow observer/navigator to safely navigate the mini-excavator around burrows to further minimize accidental burrow collapse. We attempted to adhere to at least a 4 m buffer around tortoise burrow entrances to avoid possible collapse due to the heavy machinery (Smith et al. 2015).

Prescribed burn.—Georgia Forestry personnel performed a prescribed burn at the previously surveyed study site on 16 September 2016 to remove ground cover that could hinder detection of smaller tortoise burrows. The site was divided into five units (Units 0-4) with fire breaks to assist with the burn logistics and safety concerns. The southernmost unit (Unit 0, 4.5 ha), closest to the home of the landowner, was not burned; we applied fire to the four northern units (Units 1–4, 11.6 ha total; Fig. 1, Left). The five units varied widely in vegetation and groundcover. Units 1–3 were dominated by *Q. laevis*, *A. stricta*, *S. repens*, and *Pinus* spp., while Unit 4 was generally more mesic than the other four units, and vegetation was primarily comprised of *A. stricta*, *Ilex* spp., and scattered *P. elliottii*. Unit 0 was dominated by modified pasture and lawn with scattered buildings and therefore fire was not needed for optimal detectability.

We were not able to excavate all burrows found and burrow-scoped during pre-burn surveys prior to the prescribed burn due to time constraints; however, following the burn, we navigated back to all remaining burrows detected pre-burn using the GPS and re-flagged them if necessary. Additionally, we conducted further surveys across the site to locate any additional burrows that had not been detected prior to the burn before continuing with the remaining burrow excavations. We concluded excavations 30 October 2016 once no additional burrows were found during surveys across the site.

We used a GIS to exclude GPS waypoints outside of the designated site units; thus, totals presented solely reflect those burrows located within the designated burn units. We tallied pre-burn and post-burn burrows across each unit by size class/burrow type and analyzed for differences between pre- and post-burn burrow detections using a Wilcoxon sign rank test for paired data ($\alpha = 0.05$). We used Microsoft Excel (2019) and SPSS® v26 for all data management and analyses.

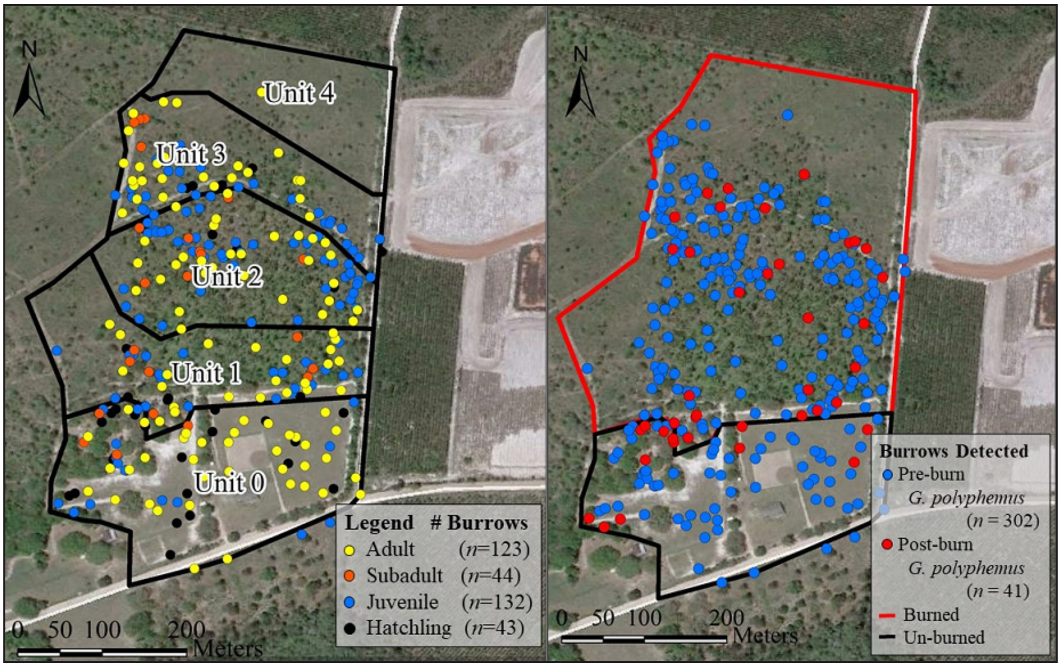

Figure 1. (Left) The distribution of all Gopher Tortoise (*Gopherus polyphemus*) burrows by size class at the Mission Mine study site, Charlton County, Georgia, USA (as identified during pre- and post-burn surveys). Notice the high incidence of smaller size class *G. polyphemus* burrows. The site is subdivided into four vegetated burn units (Units 1-4) and a single partially developed unit (Unit 0) which was not burned. Unit 0 was not burned due to the presence of the landowner's home, lawn, modified pasture, and several scattered buildings. Unit 4 was generally more mesic than the other four site units and therefore was nearly devoid of tortoise burrows. (Right) Distribution of Gopher Tortoise (*Gopherus polyphemus*) burrows detected during surveys within burned and unburned areas of the Mission Mine study site, Charlton County, Georgia, USA. (Aerial images from Google Earth).

Results

The survey site units ranged in size from 2.24–4.53 ha (Fig. 1). *Gopherus polyphemus* burrow distribution was relatively uniform across the five site units with the exception of the largely mesic Unit 4 (Fig. 1). The burned site units totaled 11.6 ha and the single unburned unit was 4.5 ha.

Overall, we detected 414 *G. polyphemus* and *D. novemcinctus* burrows in the 16.1 ha study area. We located 323 burrows prior to the burn and an additional 91 post-burn, which translates to 28% of the detected burrows that were identified immediately after the burn. Specifically, during both pre- and post-burn surveys, we detected a total of 343 *G. polyphemus* burrows across the study site (Fig. 1). We detected 302 *G. polyphemus* burrows during pre-burn surveys (Table 1, Fig. 1). We detected an additional 41 *G. polyphemus* burrows during post-burn surveys (14% of total *G. polyphemus* burrows detected; Fig. 1). We detected 72 *D. novemcinctus* burrows across the study site, of which we identified 50 *D. novemcinctus* burrows solely during post-burn surveys (Table 1, Fig. 2). The number of burrows we detected post-burn was significantly higher than the number we detected in the pre-burn surveys ($Z = -2.032$, $P = 0.042$), with the greatest increases in detectability driven by juvenile *G. polyphemus* and *D. novemcinctus.*

We successfully detected all occupied adult *G. polyphemus* burrows during pre-burn surveys; however, we did detect two additional unoccupied adult *G. polyphemus* burrows during post-burn surveys (2%

Table 1. Number and size class of burrows of Gopher Tortoises (*Gopherus polyphemus*) and Nine-banded Armadillos (*Dasypus novemcinctus*) detected during pre- and post-burn surveys within each of the five site units at the Mission Mine study site, Charlton county, Georgia, USA. Abbreviations are A = adult tortoise burrows, S = subadult tortoise burrows, J = juvenile tortoise burrows, H = hatchling tortoise burrows, and ARM = armadillo burrows.

Site Unit/Survey Period	A	S	J	H	ARM	All
Unit 0 Pre-Not burned	37	5	12	18	1	73
Unit 0 Post-Not burned	0	0	5	7	0	12
Unit 1 Pre-burn	24	12	22	4	7	69
Unit 1 Post-burn	1	1	7	3	7	19
Unit 2 Pre-burn	31	15	52	5	4	107
Unit 2 Post-burn	1	1	4	1	13	20
Unit 3 Pre-burn	28	10	21	4	10	73
Unit 3 Post-burn	0	0	9	1	12	22
Unit 4 Pre-burn	1	0	0	0	0	1
Unit 4 Post-burn	0	0	0	0	18	18
Total	123	44	132	43	72	414

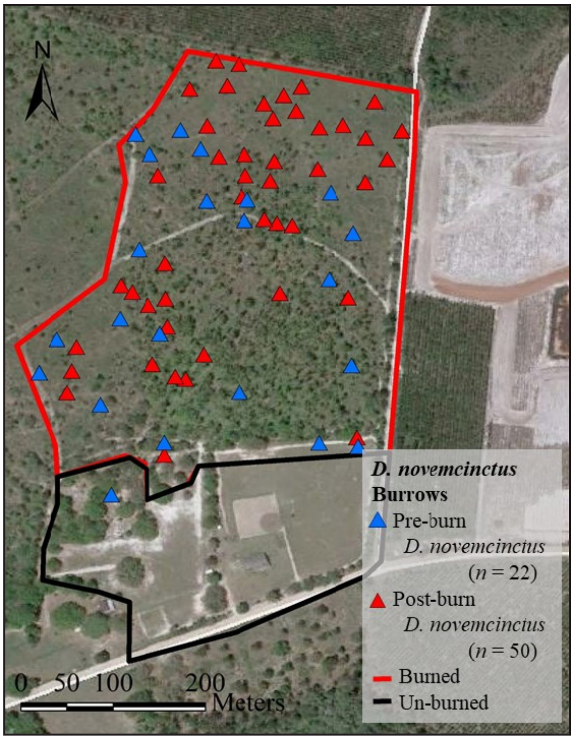

Figure 2. Distribution of Nine-banded Armadillo (*Dasypus novemcinctus*) burrows detected during surveys within burned and unburned areas of the Mission Mine study site, Charlton County, Georgia, USA. (Aerial image from Google Earth).

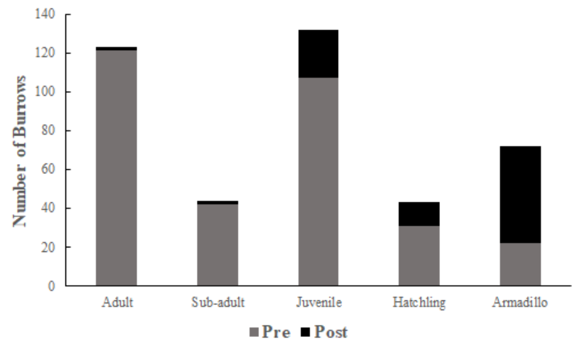

Figure 3. Various size classes of Gopher Tortoise (*Gopherus polyphemus*) and Nine-banded Armadillo (*Dasypus novemcinctus)* burrows detected within burned site units during pre- (gray bars) and additional burrows detected during post-burn surveys (black) at the Mission Mine study site, Charlton County, Georgia, USA.

increase in burrow detection during post-burn surveys; Table 1, Fig. 3). For the rest of the size classes, we detected an additional 39 *G. polyphemus* burrows during post-burn surveys (22%) overall (Table 1, Fig. 3). By age class, we detected 39% more hatchling burrows (pre = 31, post = 43), 23% more juvenile burrows (pre = 107, post = 132), and 5% more subadult burrows (pre = 42, post = 44; Table 1, Fig. 3).

We detected more than twice as many *D. novemcinctus* burrows during post-burn surveys than during pre-burn surveys (227%; pre = 22, post = 70; Table 1, Fig. 3). In particular, we detected many additional *D. novemcinctus* burrows in Unit 4 post-burn that were previously hidden beneath *S. repens*. This is likely due to increased visibility beneath burned *S. repens* bunches (which are also a favored structure for juvenile *G. polyphemus* to burrow beneath). Additionally, we found two Florida Box Turtles (*Terrapene baurii*) sheltering inside two *D. novemcinctus* burrows several days post-burn, and a third *T. baurii* was found that had been incidentally killed on the surface during the prescribed burn in the same vicinity. We detected 109 *G. polyphemus* within burrows via the use of our burrow scope. Of these, 19 of the *G. polyphemus* individuals were found during post-burn surveys.

Discussion

Multiple factors derived from reduced visibility due to vegetation and variation in surveyor experience can influence the detectability of *G. polyphemus* burrows, with fewer detections of younger age-class tortoises that create smaller burrows that are cryptic when placed under vegetation (Pike 2006; pers. obs.). Burrow site selection is influenced by a suite of factors, including but not limited to land cover type, understory density and herbaceous cover, distance to habitat edge, density of surrounding burrows (Lau and Dodd 2015), along with mid-story canopy closure (Jones and Dorr 2004). Further, Aresco and Guyer (1999) found that there was a positive correlation between the age of an active *G. polyphemus* burrow and tree basal area and density. Although we did not record vegetation metrics at each burrow, these influences are consistent with our observations at our study site. Accurately predicting suitable *G. polyphemus* habitat is more complex than simply identifying associative soil and vegetation type, and the most effective models also include topography and other landscape features (Aresco and Guyer 1999; Kowal et al. 2014). Beyond ecological factors, surveyor experience can weigh heavily on detection probability and how a burrow is classified based on external characteristics (Smith et al. 2005).

Some of these factors can be more easily overcome than others, and we found that vegetation and debris can still inhibit detection, suggesting that no single technique will be perfect. Importantly, understanding where biases can be mitigated in the survey design of a project, and at a particular study site, will allow for the most effective and thorough biological assessment. While Line Transect Distance Sampling (LTDS) is efficient for obtaining *G. polyphemus* population estimates at large sites provided the survey area is well defined and the population density is not low (Smith et al. 2009), the accuracy of LTDS is dependent upon the percentage of habitat surveyed and a burrow occupancy estimate (Smith et al. 2009). In a comparison study of total burrow counts versus LTDS, Stober and Smith (2010) observed that their total count surveys did not meet the assumption of 100% burrow detection. Our survey methodology can be repeated at a field site to more closely approach the assumption of 100% detection of the total burrow count at sites where adequate surveyors are available and detection is critical, such as in the instances of pre-impact relocations. By systematically and repeatedly surveying an entire area until no new burrows are discovered, detection probability is asymptotically increased and the effects from biases of habitat and surveyor experience are further mitigated.

In this study, prescribed fire was applied as an additional measure to reduce detection limitations by successfully clearing the dense herbaceous groundcover that allowed us to find many additional *G. polyphemus* and *D. novemcinctus* burrows. Burrows detected during post-burn surveys comprised nearly 22% of all burrows detected at this site. The majority of additional *G. polyphemus* burrows were those of juveniles and hatchlings, which would have remained undetected without extensive surveying post-burn. Specifically, as many as 19 of 102 individual tortoises (18.6%) at this site would have been undetected had we not conducted thorough post-burn surveys.

This project occurred coincidentally (unbeknownst to the authors) with a study at a different site in Georgia, conducted by colleagues Howze and Smith (2019), who also located more *G. polyphemus* burrows post-burn, with the greatest increase in detection being that of hatchling and juvenile burrows (< 12 cm). We observed an increase in detection of burrows of all *G. polyphemus* age classes in both studies; however, they observed a 64% increase in the number of burrows detected following a prescribed burn whereas we observed a 28% increase. We speculate that this difference is likely driven by variation in habitat types, vegetation densities, and the amount of land covered in our respective studies rather than a surveyor bias.

As each *G. polyphemus* becomes increasingly important across a range-wide declining population, surveys in areas to be impacted by development should be as effective as possible. Further, if the *G. polyphemus* is listed as a federally protected species throughout its range, increasing detection and reducing incidental take will be both a matter of conservation ethics and regulatory requirement. Typically, the allocation of resources for these survey efforts is justified based on the premise of avoiding and mitigating impacts to threatened and endangered species; however, surveys that are issued as a matter of regulatory compliance offer an opportunity to conduct meaningful conservation and mitigation for the broader wildlife community. Prescribed fire can be a very effective tool for greatly improving burrow detection and relocation efficiency for *G. polyphemus*, along with many commensal species. Within the area of focus for this study, we observed and relocated 12 species of commensals in and around *G. polyphemus* burrows that represented small and meso-mammals, amphibians, reptiles, and arachnids. The diversity we observed in a matter of months reinforces the relevance of our methods to multiple species and taxonomic groups. While prescribed fire is typically applied as a habitat management tool in fire-dependent ecosystems (Heuberger and Putz 2003; Mitchell et al. 2006; Lavoie et al. 2010), its usefulness should not be overlooked elsewhere when it can be employed without risk to native plant and animals.

Additionally, this is the first report to our knowledge where *D. novemcinctus* burrows were surveyed, burrow-scoped, and excavated or collapsed simultaneously alongside tortoise burrows as part of an ecosystem-focused impact mitigation effort. It should be noted that since this site was surveyed, the authors have observed several *G. polyphemus* using *D. novemcinctus* burrows elsewhere at the Mission Mine study site. Documentation of commensal usage of *D. novemcinctus* burrows is increasing (pers. obs.) and we recommend that future relocation work should survey these burrows as part of standard protocols before land-impacting activities are conducted.

While the objective of this study was to locate *G. polyphemus*, prescribed fires can also improve the detection and conservation management of multiple species. Various commensal species of concern are known to regularly use underground refugia, warranting a need for increased detectability of such microhabitat structure. As a prominent example, the federally listed *D. couperi* is an important commensal of consideration. While *D. couperi* are found most frequently near *G. polyphemus* burrows (Diemer and Speake 1983), they will use a variety of shelters, such as the burrows of *D. novemcinctus* and other mammals, root and stump holes, and windrows (Lawler 1977; Moler 1985; Hyslop 2007). One study specifically outlined methods of finding *D. couperi* in Georgia by conducting broader searches that include *G. polyphemus* burrows, *D. novemcinctus* burrows, and refugia of similar structure (Stevenson et al. 2003). Additionally, Hyslop et al. (2009) found a strong association between *G. polyphemus* burrows and *D. couperi* winter refugia and suggested that *D. couperi* are likely limited in their northern extent by availability of suitable underground winter refugia sites. Hyslop et al. (2009) also reported *D. couperi* occasionally using *D. novemcinctus* burrows in addition to *G. polyphemus* burrows and other refugia sites such as stump/root holes. As another example, Eastern Diamondback Rattlesnakes (*Crotalus adamanteus*), which have been petitioned for federal listing under the U.S. Endangered Species Act, are also known to occupy *D. novemcinctus* burrows (Martin and Means 2000) along with other various underground refugia (Bauder et al. 2017). During our surveys at this site, we encountered species of conservation concern such as *L. capito* and *P. m. mugitus* using *G. polyphemus* burrows despite the absence of *D. couperi* and *C. adamanteus.* The only vertebrates encountered in *D. novemcinctus* burrows during these surveys were two *T. baurii* following the prescribed burn; however, we have since observed juvenile *G. polyphemus* in nearby mine site areas using inactive *D. novemcinctus* burrows.

One of our greatest concerns with relocation is ensuring that no *G. polyphemus* or vertebrate commensal species are overlooked prior to anthropogenic habitat impacts. By stringently surveying an area using 100% coverage survey methods both prior to and following a prescribed burn, we demonstrated that these methods greatly increase the familiarity of surveyors with the site and substantially increase the detection of both *G. polyphemus* burrows and *D. novemcinctus* burrows. Highly effective detection methods further our ability to augment recipient site populations, which will assist us in more rapidly achieving minimum viable population sizes of *G. polyphemus* at protected recipient sites. Further, these populations will consist of a more representative demographic distribution rather than younger age classes being differentially reduced due to a higher take of undetected juvenile *G. polyphemus.*

This case study provides a method that allows for a higher degree of confidence in burrow detectability, which may allow for more effective and efficient population mitigation. Our take-away recommendation for surveyors to conduct thorough surveys that aim for 100% coverage, be attentive to microhabitat features that can conceal cryptic signs of wildlife presence, and engage land management techniques, such as prescribed fire, that increase detectability of wildlife extends far beyond burrowing vertebrate species in upland ecosystems of the southeastern U.S. This conservation need is applicable in areas across the globe that are undergoing development and arguably in all places where we have the opportunity to put forward our best attempt at avoiding and reducing the mortality of native wildlife.

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Lance Paden conducted this research through his position as a Research Professional II while he was a graduate student at the Odum School of Ecology, University of Georgia, Athens (UGA), USA. He graduated from UGA in May 2018 with his M.S. in Conservation Ecology and Sustainable Development through the Applied Wildlife Conservation Lab. His research interests generally involve using applied techniques to simultaneously further herpetological research and conservation objectives. Much of his recent work has revolved around managing the field operations of Gopher Tortoise translocation events for Southern Ionics Minerals, LLC, as well as studying the spatial, thermal, and health effects associated with translocation. (Photographed by Maranda Miller).

Kimberly M. Andrews is Research Faculty with the Marine Extension and Georgia Sea Grant, the University of Georgia (UGA) Odum, Athens, USA, where she also received a Ph.D. in Ecology and an M.S. in Conservation Ecology and Sustainable Development. She manages the Applied Wildlife Conservation Lab, which operates out of the UGA Marine Extension facility in Brunswick, Georgia, USA. The integrated research conducted in her lab focuses on wildlife ecology and health, human-wildlife interactions and conflict resolution, and the effects of climate change on ecological habitats and built infrastructure, and our resulting ability to manage for healthy ecosystems. (Photographed by Kimberly M. Andrews).

Carmen Candal earned her B.S. in Fisheries and Wildlife at the Warnell School of Forestry and Natural Resources at the University of Georgia, Athens (UGA), USA and is currently a Graduate Research Assistant through the Warnell School pursuing her Master's in Wildlife Ecology and Management. She worked with the Applied Wildlife Conservation Lab as a Gopher Tortoise technician for surveys, relocations, and post-relocation monitoring. Her current research focuses on the movement, survival, and stress physiology of head-started Mojave Desert Tortoises (Gopherus agassizii). (Photographed by Mandy Leach).

Jim Renner is the Manager of Environmental Stewardship for Southern Ionics Minerals, LLC, Saint Simons Island, a heavy mineral sand mining company in southeast Georgia, USA. Mr. Renner is a Geologist and Environmental Planner with 30+ y of experience on a wide variety of water supply, environmental impact assessment, mining and mineral processing, and natural resource management projects. (Photographed by James Renner).