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RESEARCH ARTICLE

Experimental translocation for restoration of an ecosystem engineer

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The longleaf pine (*Pinus palustris* Mill.) savanna ecosystem in North America has declined by 97% from its historic range and its restoration is a conservation priority. The southeastern pocket gopher (*Geomys pinetis*), an ecosystem engineer in longleaf pine savannas, is absent from most of its historic range. Translocation of pocket gophers may be needed to reestablish ecosystem services of restored longleaf savannas. To determine translocation feasibility, we quantified survival, site fidelity, and homing of pocket gophers translocated using soft releases (with a starter burrow system; $n = 13$), hard releases (without a starter burrow system; $n = 17$), or released into their own burrows (control; $n = 10$). Naïve survival was 46 and 35% for soft- and hard-released individuals, respectively, and 80% for controls. Most mortalities of translocated individuals (75.0%) occurred within 12 days. Including all radiotagged pocket gophers, daily survival of soft-released animals ($\widehat{S} = 0.990$) was intermediate between hard-released ($\widehat{S} = 0.986$) and controls ($\widehat{S} = 0.993$), and only hard-released was lower than controls. Using only individuals that survived greater than 14 days, we found no difference in daily survival. Site fidelity was low, with 70% of translocated pocket gophers making aboveground movements away from release point. However, soft-released individuals stayed at the release point three times longer than hard-released animals. No pocket gopher exhibited homing. Our results suggest translocation has potential for establishing pocket gopher populations into restored longleaf pine savannas and that mitigating mortality during establishment will increase the likelihood of success.

Key words: ecosystem engineer, *Geomys pinetis*, pocket gopher, savanna ecosystems, survival, translocation

Implications for Practice

- Restoring savanna ecosystems may require fauna restoration to meet goals for biodiversity and ecosystem function.
- Ecosystem engineers, like pocket gophers, are vital because they modify soil and vegetation.
- Translocation of pocket gophers is a viable option for reintroduction into restored open pine systems.
- Soft-release techniques provided short-term refugia, aiding pocket gopher survival.

Introduction

Translocation is a viable technique for reestablishing populations of at-risk species into areas where they have been extirpated (Griffith et al. 1989; Van Vuren et al. 1997; Fischer & Lindenmayer 2000). However, not all translocations are successful, and multiple factors can influence success. Chronic stress from capture and handling followed by release into a novel environment can lower translocation success (Dickens et al. 2010). Because translocated individuals are placed into a novel environment, they face the immediate challenge of finding food and shelter (Dickens et al. 2009), which typically leads to increased predation risk (Cowan 2001). Furthermore, homing (attempted movement from release areas back to capture sites) can cause stress, increased predation, or starvation, consequently decreasing success (Van Vuren et al. 1997; Hinderle et al. 2015). To mitigate these factors, soft-release protocols often are used in translocation efforts. Although methods vary, soft release typically includes an acclimatization period in a location that provides safety from predators and food supplementation (Resende et al. 2021). Compared to

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hard release, where neither increased safety nor food are provided, soft-release protocols can increase success by up to 45% (Resende et al. 2021). Soft-released animals typically remain closer to the release site, a primary factor contributing to translocation success. Although numerous techniques have been used successfully with terrestrial mammals, soft-release protocols for fossorial species have received less attention (Truett et al. 2001; Hansler et al. 2017; Pynne et al. 2019).

The southeastern pocket gopher (*Geomys pinetis* Rafinesque; hereafter, pocket gopher) is a fossorial herbivore associated with longleaf pine (*Pinus palustris* Mill.) savannas of the southeastern United States (Pembleton & Williams 1978). Pocket gophers function as ecosystem engineers, promoting ecosystem diversity and resilience (Reichman & Seabloom 2002; Lynn et al. 2018). Their burrow systems aerate soils and aid in nutrient cycling, and the soil mounds created from burrowing provide bare ground for herbaceous plant colonization (Reichman & Seabloom 2002; Simkin et al. 2004; Clark et al. 2018). In addition, pocket gopher burrow systems provide shelter for many faunal species (Funderburg & Lee 1968; Skelley & Kovarik 2001). Thus, reintroducing pocket gophers may play an important role in longleaf pine savanna restoration (Huntly & Reichman 1994; Reichman & Seabloom 2002; Simkin & Michener 2005).

The longleaf pine savanna ecosystem is imperiled, and over the last few decades there have been extensive restoration efforts (Van Lear et al. 2005). Like many other savanna systems, fire exclusion drastically reduced endemic floral and faunal diversity (Van Lear et al. 2005; Means 2006; Nowacki & Abrams 2008). Restoration activities in longleaf savannas aim to reestablish vegetation structure, typically by promoting a mature pine overstory with an open canopy and reintroducing fire to maintain understory structure and composition (Van Lear et al. 2005). Concurrent restoration of faunal communities in longleaf pine savannas would increase biodiversity and enhance overall system function (Conner & Cherry 2017; Smith et al. 2017).

Southeastern pocket gopher populations have declined over the past 40–50 years, and it has been designated a Species of Greatest Conservation Need in all three states in which it occurs (Florida Fish and Wildlife Conservation Commission 2012; Alabama Department of Conservation and Natural Resources 2015; Georgia Department of Natural Resources 2015). Declines have been driven by habitat loss and fragmentation due to urbanization and habitat degradation resulting from decades of fire suppression (Duncan et al. 2020). Although longleaf savanna restoration efforts may provide suitable habitat, southeastern pocket gopher colonization is not guaranteed due to the limited dispersal abilities of pocket gophers relative to more vagile mammals (Hafner et al. 1998). Translocation represents a potential management approach for reestablishing populations into restored habitats, but few studies have examined the efficacy of pocket gopher translocation. Hansler et al. (2017) observed low mortality in translocated maritime pocket gophers (*Geomys personatus maritimus* Davis) and that individuals generally reamined near the release area, indicating translocation as a potential management option. Pynne et al. (2019) observed increased movements by translocated southeastern pocket gophers leading to high predation rates. They suggested that soft-release approaches to limit aboveground movements may lower predation risk and increase translocation success. However, more information is needed to determine the viability of translocation, especially related to optimal release type to limit aboveground movements and increase survival. Therefore, our goals were to quantify survival, site fidelity (as a measure of establishment), and homing behavior as measures of success to determine feasibility and provide data for establishing a protocol for southeastern pocket gopher translocation. We compared metrics among a soft-release protocol, hard release, and control (released back into their own burrow system). We predicted that soft release would increase survival and site fidelity relative to hard release because established burrow systems would provide protection from predators and reduce initial energetic cost of burrowing (Bright & Morris 1994; Sacerdote-Velat et al. 2014; Resende et al. 2021).

Methods

Research Sites

We selected the Jones Center at Ichauway, an 11,700 ha managed longleaf pine-dominated forest in Baker County, Georgia, U.S.A. (hereafter, Ichauway), as our source of pocket gophers for translocation (hereafter, donor area) due to access and presence of an established pocket gopher population (Smith et al. 2006; Warren et al. 2017*a*, 2017*b*; McIntyre et al. 2019) (Fig. 1). Areas that received pocket gophers (hereafter, translocation areas) included Ichauway (in areas with no evidence of pocket gopher presence), Silver Lake Wildlife Management Area in Decatur County, Georgia (Silver Lake) and a private property in Baker County, Georgia. Silver Lake is a State of Georgia-owned 3,720-ha property consisting of longleaf and other open pine systems managed using herbicide and prescribed fire. The private property is a 105-ha area managed with mechanical thinning and prescribed fire. Translocation areas were selected based on proximity to the donor site, open pine savanna as the dominant land cover, soil texture with less than 10% clay (Warren et al. 2017*a*; Bennett et al. 2020), and up to 3 years since the last fire (Gates & Tanner 1988). Land cover characteristics were determined using the National Landcover Database 2011 data (Homer et al. 2015) and soil textures from the Soil Survey Geographic Database (Soil Survey Staff 2018). Recent and frequent fire history for translocation areas, determined from landowner records, was included as a criterion because fire is used to promote and maintain the herbaceous understory characteristic of longleaf savannas which provides food for pocket gophers (Gates & Tanner 1988; Van Lear et al. 2005).

We used ArcMap 10.5 (ESRI 2016) to identify 500 × 500 m squares of suitable habitat at each translocation area as specific release sites (one release site at Silver Lake, two sites on the private property, and two release sites at Ichauway). Mean distance from donor to translocation sites was 22 km (2–60 km). Prior to translocation, each release site was surveyed using line transects every 50 m to ensure pocket gopher absence. Next, we randomly generated specific translocation release points within each release site. A minimum of 30 m was established between

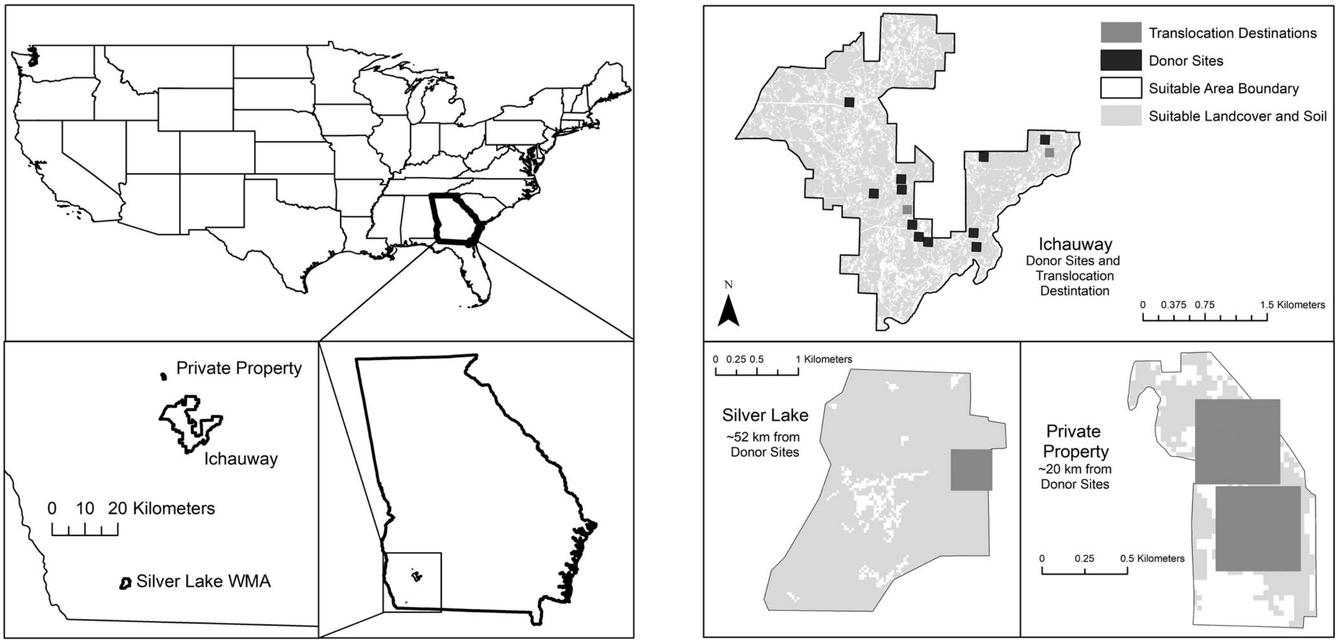

Figure 1. Left: Locations of study areas used to examine feasibility of southeastern pocket gopher (*Geomys pinetis*) translocation in southwestern Georgia, U.S.A., June 2018–August 2019. Study areas included The Jones Center at Ichauway (donor and translocation area), Silver Lake Wildlife Management Area (translocation area), and a privately owned property (translocation area). Right: Locations of donor and translocation destination sites within study areas.

release points (mean = 111 m; range = 33–378 m) to ensure adequate spacing based on southeastern pocket gopher mean home range size (930 m^2; Warren et al. 2017*b*).

Translocations

To capture individuals, we excavated recently created pocket gopher mounds and placed traps inside the burrow. We primarily used 9 × 9 × 30 cm Sherman live traps (H.B. Sherman, Tallahassee, FL) placed upside down in burrows (Hansler et al. 2017) because they were more effective than trap types described by Hart (1973), Connior and Risch (2009), and Moore et al. (2019). We trapped pocket gophers continuously from 8 July 2018 to 11 May 2019 until 40 adult/subadult individuals were captured.

We transported captured animals individually in 38 L glass aquaria partially filled with soil and roots collected from their capture areas. We surgically implanted 3G VHF transmitters (148–149 MHz; Model SOPI-2070; Wildlife Materials Inc., Murphysboro, IL, U.S.A.) with an estimated 120-day transmitter battery life into the abdominal cavities of adult and subadult (>100 g) individuals (Hansler et al. 2017; Warren et al. 2017*b*; Pynne et al. 2019). The first five surgeries were conducted at the University of Georgia School of Veterinary Medicine up to 24 hours after capture under the supervision and training of a veterinarian. The first three individuals were anesthetized with continuously inhaled isoflurane. Because using an isoflurane pump in the field was not feasible, we tested use of intraperitoneally injected anesthesia on two individuals, with no apparent negative effects. The remaining surgeries ($n = 35$) were conducted at Ichauway in the field within 1 hour of capture using the intraperitoneally injected anesthesia combination of ketamine (100.0 mg/mL at 13.0 mg/kg), xylazine (20.0 mg/mL at 2.6 mg/kg), and midazolam (5.0 mg/kL at 1.3 mg/kg). If individuals did not reach a stable plane of anesthesia within 5 minutes after the initial dose, up to three additional ketamine doses at 4.3 mg/kg each were given. We also intraperitoneally administered buprenorphine (0.02 mg/mL at 0.02 mg/kg) and meloxicam (5 mg/kL at 0.2 mg/kg) and used a topical application of bupivacaine (0.25% solution at 2.0 mg/kg) and lidocaine (1.0% solution at 4.0 mg/kg) for pain management. We administered 60 mg/kg of subcutaneous lactated Ringer's solution in a fluid bolus before surgery to maintain hydration. We sealed the surgical incision using sutures and tissue glue (Hernandez et al. 2010). After surgery, pocket gophers recovered in 8-L plastic containers filled with aspen bedding and a heating pad. Once awake and ambulatory, we transferred the gophers back into the 38 L aquaria and we released them within 12 hours of capture. Pocket gopher capture, housing, transmitter implantation, and translocation were approved by the Institutional Animal Care and Use Committee of the University of Georgia (AUP# A2016 05-008-Y3-A1, A2017 11-003-Y2-A4).

We randomly assigned individual pocket gophers to one of three translocation treatments: hard release (nine female, eight male), soft release (five female, eight male), and control (five female, five male). To facilitate pocket gopher population establishment, we strove to maintain an equal sample size and sex ratio at each translocation area (Table S1), but ultimate sample sizes were dependent upon capture success and logistical constraints. We placed hard-released pocket gophers into a 1-m

Figure 2. (A) Burrow building plow and (B) resulting burrow used in translocation of 15 southeastern pocket gophers (*Geomys pinetis*) in southwestern Georgia, U.S.A., from June 2018 and August 2019.

diameter × 0.25-m deep hole following Pynne et al. (2019). For soft releases, we placed pocket gophers into starter burrows consisting of two, approximately 25-m long, 25-cm deep intersecting burrows created using a burrow building plow pulled behind a tractor, similar to Hygnstrom et al. (2010) (Fig. 2). Starter burrow depth was based on the mean depth of burrows excavated during trapping on the donor area. In both approaches, we constructed 3 × 3 m barriers from silt fencing buried approximately 10–15 cm belowground surrounding release holes/burrow entrances (fencing was approximately 2.5 m from the hole/burrow) to minimize potential aboveground movement (Warren et al. 2017*b*; Pynne et al. 2019). Initially, we provided supplementary food (e.g., potatoes, sweet potatoes, turnips, and carrots) in the burrows' entry hole, which was not reprovisioned. We released control pocket gophers back into their home burrows.

Tracking

We radiotracked pocket gophers ($n = 40$) from 7 July 2018 to 20 June 2019. Tracking sessions occurred every other day within a site. During a tracking session, we located each pocket gopher during daylight hours starting at a randomly generated time each day, and individuals were tracked in random order. We georeferenced pocket gopher locations and mounds created since the previous tracking session using a Geode submeter receiver and Archer2 Global Position System unit (Juniper Systems, Logan, UT, U.S.A.). When mortalities occurred aboveground, we attempted to determine the cause by examining recovered carcasses. If pocket gophers remained in the same position belowground for 2 weeks, we assumed mortality and exhumed the carcass. When pocket gophers could not be located after several tracking attempts, we searched for additional mounding in the area of the last location to determine if signal loss was due to transmitter failure (Pynne et al. 2019). If no mounding was observed, we assumed a predator carried the individual beyond transmitter range because of pocket gophers' limited aboveground mobility (Hickman & Brown 1973*a*; Williams & Baker 1976).

Analyses

Most survival analyses exclude data from a period following initial capture to reduce effects of capture stress and radio tagging on survival analyses (Conner 2001; Morris et al. 2011). Because our primary objective was to evaluate translocation as a restoration tool, effects of capture stress were important to include in our survival analyses of translocated animals. Therefore, we did not eliminate time following initial capture when estimating survival. However, because survival estimates of southeastern pocket gophers are rare, we also conducted a second, more traditional survival analysis in which we excluded the first 14 days following capture. For both analyses, we estimated daily survival rates for each translocation treatment with a Kaplan–Meier (K-M) staggered entry survival analysis (Kaplan & Meier 1958) using the "survival" package (Therneau 2015) in R (version 4.0; R Foundation for Statistical Computing, Vienna, Austria). Because we recorded no mortalities among translocated animals after 28 days, we censored all animals at 90 days for survival analyses. Differences in survival rates between treatment pairs and sexes were determined using K-M log rank tests (Harrington & Fleming 1982; Conner 2001). We also used K-M log rank tests to compare daily survival rates among translocation areas using the full dataset (including the first 14 days) and only including translocated individuals. We calculated naïve survival as the percent of individuals surviving until expected transmitter failure (approximately 120 days) for comparison with other studies (Van Vuren et al. 1997; Cowan 2001).

We assessed site fidelity by determining if pocket gophers remained where released or made aboveground movements (Pynne et al. 2019). If animals were located greater than 10 m from the previous location (2 days prior) without producing mounds in-between, we assumed the movement was made aboveground as southeastern pocket gophers typically produce 1–2 mounds/linear meter of burrow excavated (Goode 1875; Hickman & Brown 1973*b*). All individuals were used for analysis of site fidelity. We used 2 × 2 contingency tables and χ^2 tests to determine if site fidelity differed between hard and soft release, and if all translocated individuals (hard and soft release combined) differed from control individuals. We used a 3 × 2 contingency table and χ^2 tests to examine whether site fidelity varied among translocation areas. We used analysis of variance to determine if translocation treatment (hard or soft release) affected the time (days) that individuals stayed within 10 m of the release point.

Pocket gopher mounds generally indicate the direction of tunnels and can be used to examine directional movements indicative of homing (Hansler et al. 2017). Using animals that survived more than three consecutive tracking sessions, we measured deviations of pocket gopher mound trajectories (mean direction of mounds produced during the tracking period) or aboveground movements from a straight line between release and capture sites in ArcMap 10.5 (ESRI 2016). Angles less than 45° from release to capture sites were considered indicators of homing behavior (Hansler et al. 2017).

Results

Naïve survival was 35% (6/17) and 46% (6/13) for hard- and soft-released individuals (40% combined), respectively, and 80% (8/10) for control animals. Most mortalities (75%) of translocated individuals occurred within the first 12 days, and the last mortality was observed on day 28. Of individuals for which fate was determined, one died due to broken sutures from surgery, one from avian predation, and one from timber rattlesnake (*Crotalus horridus*) predation (all three were hard released). Predation was assumed for six animals (two control, three hard-released, one soft-released) because signals were lost before expected transmitter battery failure concurrent with cessation of mounding. The remaining 11 mortalities (0 control, 5 hard-released, 6 soft-released) occurred within 2 weeks of release; although we recovered 10 carcasses, cause of mortality could not be determined in field examinations.

When all animals were included in analyses regardless of when they died, daily survival of control animals ($\widehat{S} = 0.993$; 95% confidence interval [CI] = 0.983–1.0) was similar to soft released (Fig. 3; K-M test; $\chi^2_1 = 2.7$, $p = 0.10$), but greater than hard released ($\chi^2_1 = 5.4$, $p = 0.02$), and daily survival did not differ ($\chi^2_1 = 0.7$, $p = 0.40$) between hard ($\widehat{S} = 0.986$; 95% CI = 0.977–0.995) and soft-released ($\widehat{S} = 0.990$; 95% CI = 0.983–0.998) animals. Including only individuals that survived the first 14 days of monitoring, daily survival rates were similar (Fig. 4.; $\chi^2_2 = 0.3$, $p = 0.90$) among hard-released ($\widehat{S} = 0.988$; 95% CI = 0.972–1.0), soft released ($\widehat{S} = 0.991$; 95% CI = 0.975–1.0), and control ($\widehat{S} = 0.993$; 95% CI = 0.983–1.0) animals. Across translocation treatments, daily survival was similar ($\chi^2_1 = 0.1$, $p = 0.80$) between females ($\widehat{S} = 0.98$; 95% CI = 0.96–0.99) and males ($\widehat{S} = 0.99$, 95% CI = 0.98–1.0). Daily survival rate of translocated individuals was similar ($\chi^2_2 = 4.3$, $p = 0.100$) among translocation areas.

The site fidelity analysis included 17 hard-released, 13 soft-released, and 10 control pocket gophers. A total of 23 (13 hard-released, 8 soft-released, and 2 control) individuals made aboveground movements. Aboveground movements by six individuals (four hard release, two soft release) were greater

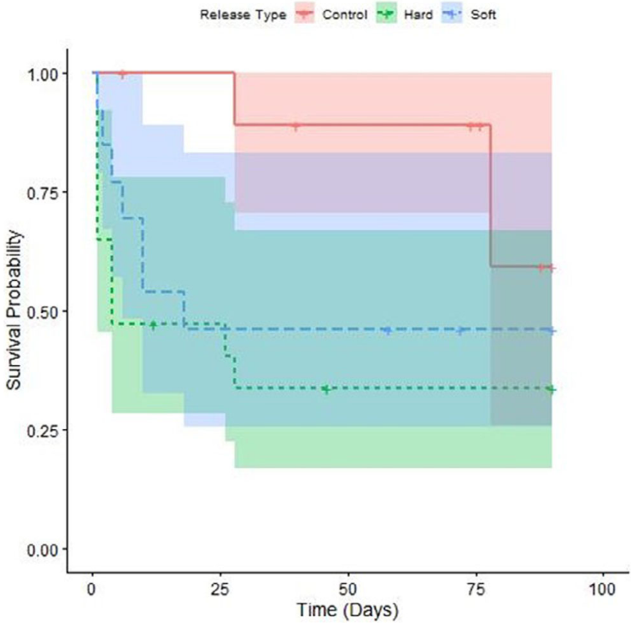

Figure 3. Estimated daily survival rate of all 40 radiotagged southeastern pocket gophers (*Geomys pinetis*) assigned to hard release ($n = 17$; 9 female, 8 male), soft release ($n = 13$; 5 female, 8 male), and control ($n = 10$; 5 female, 5 male) treatments in Baker County, Georgia. Individuals were tracked for 1–90 days between July 2018 and August 2019. Shaded areas indicate 95% CI for each translocation treatment.

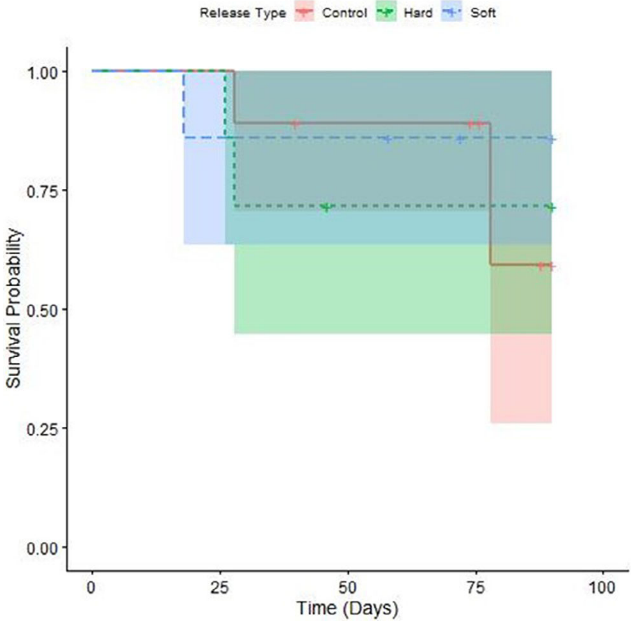

Figure 4. Estimated daily survival rate of radiotagged southeastern pocket gophers (*Geomys pinetis*) assigned to hard release ($n = 17$; 9 female, 8 male), soft release ($n = 13$; 5 female, 8 male), and control ($n = 10$; 5 female, 5 male) treatments in Baker County, Georgia, that survived greater than 14 days. Individuals were tracked for 1–90 days between July 2018 and August 2019. Shaded areas indicate 95% CI for each translocation treatment.

than 100 m. Fewer control pocket gophers (20%) made observable aboveground movements relative to translocated pocket gophers (70%) ($\chi^2{}_1 = 8.43$, $p = 0.003$). Percent of translocated pocket gophers making aboveground movements was similar ($\chi^2{}_1 = 0.78$, $p = 0.377$) between soft (62%) and hard releases (77%), and among translocation areas ($\chi^2{}_2 = 2.22$, $p = 0.329$). Of translocated pocket gophers that made aboveground movements, soft-released individuals spent significantly more time at the release point (6.0 ± 1.99 days) than hard released (2.3 ± 0.44 days) before dispersing ($F_{1,21} = 5.56$, $p = 0.030$).

No translocated pocket gophers exhibited homing behavior. Deviation angles for all individuals were greater than 45° (mean angle = 102.5° ± 34.4°), except one hard-released individual that made a single aboveground movement at 25°, but subsequently moved aboveground again 180° (directly opposite) from both capture and release point.

Discussion

Based on the results of our study and others (Warren et al. 2017*a*, 2017*b*; Pynne et al. 2019), we conclude that translocation is a viable method for restoring southeastern pocket gophers into longleaf pine savanna forests where the species has been extirpated. When translocating pocket gophers into restored areas, managers should expect a 35–46% naïve survival, depending on release approach, and for most mortalities to occur within 2 weeks of release. Thus, planning for and undertaking measures to reduce early mortality may increase translocation success. Our soft-release protocol appeared to increase survival during this early establishment period, but other approaches that keep translocated individuals at or near release sites also may increase success (Resende et al. 2021).

We could not determine the cause of most pocket gopher mortalities. Although one individual died due to broken sutures at the transmitter implantation site, handling, and surgery-related stress were unlikely causes of mortality in the remaining individuals because we had no surgery-related mortalities among control animals. Indeed, we only observed two mortalities among control animals, and both were assumed to be predation events, occurring 28 and 78 days after release. Starvation is a potential mortality factor in translocations (Bright & Morris 1994; Dickens et al. 2010); however, none of the recovered carcasses ($n = 10$) appeared emaciated. Translocated pocket gophers were exposed to the common stressors associated with relocation (Dickens et al. 2010), but fossorial animals also have the energetic requirement to create new burrows for shelter and foraging (Vleck 1979; Buffenstein 2000; Romañach et al. 2007). Thus, we posit that idiopathic mortalities resulted from the additive effects of acute environmental stressors from translocation and the energetic demands of burrowing. Vleck (1979) estimated that burrowing by pocket gophers takes 360–3,400 times more energy (depending on soil type) than moving the same distance aboveground. Although soft-released individuals were provided starter burrows, most eventually moved away from the release point. Thus, soft- and hard-released pocket gophers generally had similar energetic requirements associated with creating burrows.

Comparison of daily survival rates among treatments was ambiguous when mortalities that occurred within the first 2 weeks were included. Nonetheless, our results provide evidence that soft release may be beneficial to operational translocations. Daily survival of soft-released animals was intermediate between hard-released and controls, suggesting that the starter burrows provided a survival advantage. We observed low daily survival rates during the first 2 weeks following translocation. Lower initial survival is expected in translocation efforts (Van Zant & Wooten 2003; Moreno et al. 2004; Dickens et al. 2010). However, naïve survival of soft-released animals (54%) during the first 2 weeks was greater than hard-released (41%). Although the acute stress associated with translocation affected hard- and soft-released animals equally, having a preestablished burrow system available may have provided an advantage to soft-released animals in the days immediately following release.

Our results suggest that mitigating mortality in the period immediately following translocation will increase the likelihood of establishing southeastern pocket gopher populations using translocation (Letty et al. 2000). Given that acute stress likely was the primary cause of initial mortality, reducing the influence of environmental stressors should be a priority in pocket gopher translocation efforts. Dickens et al. (2010) proposed strategies for decreasing stress-related vulnerability of translocated animals in the release habitat. However, incorporating these strategies into translocation protocols for fossorial animals is challenging. Techniques designed to delay release allows time for animals to adjust to the new environment (Bright & Morris 1994), but fencing was not effective at preventing dispersal by pocket gophers in our study. Furthermore, supplementing food can reduce stress following release (Cabezas & Moreno 2007; Dickens et al. 2010), but all individuals in our study abandoned provisioned food. Unlike terrestrial species, fossorial species must create their own shelter and therefore may prioritize borrowing over immediately seeking food. Although we did not examine survival relative to translocation date, timing releases to coincide with abundant food availability is an important consideration (Dickens et al. 2010) and may be more effective than food supplementation.

Contrary to our expectation, soft-released pocket gophers did not exhibit long-term use of starter burrows, but importantly, stayed at the release point almost three times longer than hard-released individuals. Multiple studies have demonstrated increased translocation success in rodents using soft-release techniques that keep animals at the release area (Bright & Morris 1994; Truett et al. 2001; Cid et al. 2014). Based on their meta-analysis, Resende et al. (2021) concluded that soft-release protocols that cause individuals to remain at the release site can increase translocation success up to 77%. Preestablished burrows resulted in soft-released individuals remaining at the release point for an additional 3–4 days. We suggest that additional time in the preestablished burrows allowed soft-released pocket gophers to further recover from the acute stress of being translocated.

We observed no movements indicative of homing in translocated pocket gophers. Warren et al. (2017*b*) reported one in situ southeastern pocket gopher that left its burrow, traveled 300 m, and returned, suggesting the ability to navigate back to the burrow. However, southeastern (Pynne et al. 2019) and maritime (Hansler et al. 2017) pocket gophers translocated at least 421 m from capture sites did not exhibit homing behavior. Homing in geomyids has been documented experimentally (Cousins 2013) and in field conditions at distances up to 77 m (Howard & Childs 1959), but ability to home generally is inversely related to displacement distance (Joslin 1977; Villaseñor et al. 2013). The closest distance from donor to release site in our study was 2 km; thus, lack of homing behavior was not surprising. Although homing exposes individuals to higher predation risk and energetic cost, potentially impeding translocation efforts (Villaseñor et al. 2013), our results suggest it is not likely a concern in operational pocket gopher translocations as distances are likely to be farther than those in our study.

We used fencing to keep translocated individuals at the release point, which we expected would reduce predation risk (Pynne et al. 2019). However, fencing was not successful at preventing initial aboveground movements. All individuals eventually burrowed under the fencing, and 70% made an aboveground movement away from the release point. After moving from the release point, they assumed typical mounding behavior at the new location and largely abandoned long-distance movements. Although fencing was not effective, other means to prevent translocated individuals from moving from the release point until burrow establishment likely will increase success (Bright & Morris 1994; Truett et al. 2001; Cid et al. 2014). Acclimatization cages similar to those used in prairie dog translocations (Truett et al. 2001; Nelson & Thiemer 2012) may prevent or delay aboveground movement, but this approach has not been evaluated with pocket gophers and warrants study before implementation.

Restoration of longleaf pine savannas is a major focus for many land management agencies and private organizations in the southeastern United States (McIntyre et al. 2018). The primary focus in longleaf savanna restoration is vegetation composition and structure (Van Lear et al. 2005). However, holistic restoration requires consideration of faunal communities, as well as plant communities. Southeastern pocket gophers are the primary source of animal-generated soil disturbance in longleaf forests (Simkin & Michener 2005) and provide numerous ecosystem services (Simkin et al. 2004; Clark et al. 2018). Our results indicate that translocation is a viable management tool for establishing pocket gopher populations into longleaf pine savannas and should be considered in restoration efforts. However, we caution that our study focused on initial survival and establishment following translocation. Additional research is needed to examine long-term persistence of translocated populations. Furthermore, we suggest that future studies examine the optimal number of animals to translocate and if additional releases are necessary for population establishment. Finally, we demonstrated successful use of injected anesthesia in the field which will greatly facilitate future pocket gopher radiotelemetry studies.

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Supporting Information

The following information may be found in the online version of this article:

Table S1. Sample sizes of southeastern pocket gophers (*Geomys pinetis*) radiotracked at three release sites in Baker County, Georgia, between June 2018 and August 2019 by translocation treatment and sex.

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