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Long Distance Migrations, Landscape Use, and Vulnerability to Prescribed Fire of the Gopher Frog (*Lithobates capito*)

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Abstract.—**The Gopher Frog, *Lithobates capito*, is an endemic to upland, fire-maintained pine forests on the Southeastern Coastal Plain and requires open, isolated wetlands for breeding. This species has experienced drastic population declines because of habitat loss and degradation and now occurs only in scattered populations in the southern United States. We tracked the post-breeding movements and burrow use of 17 Gopher Frogs in the Sandhills of North Carolina using radio telemetry. Nine frogs were successfully tracked to summer refugia; the other eight frogs shed their transmitters or were killed by predators or fire during migration. Frogs traveled 0.5—3.5 km (mean = 1.3 km) between the breeding pond and a summer refugium. The 3.5-km movement is substantially longer than has been reported for Gopher Frogs before. Our results suggest that an area of 3,739 ha (9,239 acres) around breeding ponds is required to provide summer habitat for Gopher Frogs. Eight of nine frogs used holes associated with the stumps of longleaf pines for their summer refugia, and we documented fidelity to particular stumps, with one frog traveling long distances from breeding pond to the same summer refugium during two consecutive seasons. Frogs only made major movements during rainy nights. Prolonged presence on the forest floor during post-breeding migrations exposed frogs to prescribed fires conducted in the spring. Prescribed burning within several kilometers of Gopher Frog ponds should be conducted after mid-May to reduce adult mortality.**

Understanding how animals use landscapes is essential for managing habitat and guiding land conservation, preservation, and use. This is especially important for animals that use different habitats and must migrate between them, including pond-breeding amphibians. Information on amphibian movements helps biologists and managers determine the amount of upland habitat and proper management necessary to preserve populations breeding in isolated wetlands. For instance, Semlitsch and Bodie (2003) summarized available literature on movements of amphibians and reptiles that rely on both isolated wetlands and surrounding upland habitat. Based on available data for numerous species, they proposed "core areas" of protection around wetlands of approximately 350 m from the edge of an isolated wetland to protect the resident populations. They also pointed out that the typical level of regulatory "buffer" protection around isolated wetlands in most states ranges from 15–30 m.

Gopher Frogs (*Lithobates capito*) are medium-sized frogs that spend most of the year in sandy, upland habitat, remaining very close to a single burrow or a group of Gopher Tortoise (*Gopherus polyphemus*) burrows, mammal burrows, especially those made by Pocket Gophers (*Geomys pinetis*), or tree stumps that have holes associated with them (Lee, 1968; Franz, 1986; Jackson and Milstrey, 1989; Roznik et al., 2009). These frogs have very specific breeding site requirements: open-canopied upland ephemeral depression ponds, sinkhole ponds, or borrow pits with herbaceous vegetation and a relatively long hyrdoperiod lasting from fall/winter through midsummer of the following year (Moler and Franz, 1987; Bailey, 1991). Populations of Gopher Frogs have been lost to the destruction or degradation of upland, fire-maintained pine habitat in addition to the loss or degradation of suitable breeding sites (Bailey, 1991; Moulis, 1995). Besides outright destruction, much upland and wetland habitat once used by the Gopher Frog has been degraded because of lack of appropriate fire regimes, leading to encroachment of hardwoods into wetlands and canopy closure of uplands (Thurgate and Pechmann, 2007). The Gopher Frog is listed as Endangered, Threatened, or of Special Concern in all states where it occurs: North Carolina, South Carolina, Georgia, Florida, and Alabama. Additionally, the closely related Dusky Gopher Frog (*Lithobates sevosus*) now occurs only at three sites and is listed as Federally Endangered (USFWS, 2001). In North Carolina, only seven populations of Gopher Frogs are currently known to exist, all on publicly managed land (Braswell, 1993; unpubl. data).

Movement patterns of Gopher Frogs have been reported by multiple researchers, with very different results. Richter et al. (2001) examined the Mississippi Gopher Frog and reported post-breeding movements of <300 m from the breeding pond. Telemetry or mark–recapture studies of *Lithobates capito* in Florida and Georgia have found maximum movement distances ranging from 100–700 m from breeding ponds (Phillips, 1995; Greenberg, 2001; Roznik and Johnson, 2009a; Roznik et al., 2009). Observational reports of Gopher Frogs found in upland habitat suggest Gopher Frogs are capable of moving 800 m to 2 km from breeding sites (Carr, 1940; Franz et al., 1988; Roznik, 2007), but these reports were based on where frogs were found compared to the closest known breeding site. Information about the movements of the Gopher Frog in the northern part of its range does not exist. Given this limited and somewhat conflicting information, our goal was to study the movements and landscape use of Gopher Frogs to further inform sound management and conservation of areas within the range of this species.

Materials and Methods

Study Site Description.—We studied Gopher Frogs on a 6,000-ha portion of the Sandhills Game Land (SGL), a property owned and managed by the North Carolina Wildlife Resources Commission, in Scotland County. The property contains longleaf pine (*Pinus palustris*)–wiregrass (*Aristida stricta*) sandhills bisected by numerous drainages. The ecosystem is maintained on a 2–3 yr controlled burn cycle, with much of the area around our study pond burned during the growing season (April through July). Gopher Frogs on the SGL were captured at a single ephemeral upland depression pond referred to as 17 Frog Pond, Bog Hole,

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or Grassy Pond. The pond is 1–3 ha in size, depending on rainfall during a particular year and has a completely open canopy with abundant herbaceous vegetation. A 21-ha area of forest southeast of the pond was mechanically thinned to a basal area of 9.2 m^2/ha in 2009.

Trapping and Tracking Techniques.—Gopher Frogs were captured at a drift fence that encircled the pond completely. Traps alternated between paired double-ended funnel traps and 19 liter buckets spaced 25 m apart. We walked the drift fence every rainy night from November through April to capture frogs. Frogs were selected for radio telemetry if they were leaving the pond post-breeding and if their mass was more than 45 g (to keep the transmitter weight below 5% of the frog's body mass). Each frog captured was measured for total length (TL) and its mass and sex determined and photographed. The sex of frogs was confirmed by the presence or absence of vocal pouches and enlarged thumbs. Females were also obviously gravid when they were entering the pond. We identified each individual frog by taking a photograph of the left side of its face and comparing the spotting patterns to other captured or trapped frogs. Transmitters (Holohil Systems, Ltd; Model BD-2; 2 g) were attached to 14-mm plastic beaded chains (Identisys, Inc.) and clasped around each frog's waist so that the transmitter sat just anterior to the urostyle and the antenna trailed behind the frog. It took only a few minutes to fit transmitters, and frogs were released just outside the drift fence after attachment.

We tracked frogs using a digital receiver (Advanced Telemetry Systems, model R410) and a 3-element Yagi antenna. With few exceptions, telemetered frogs were tracked daily, and in all cases, frogs were tracked immediately before and after rainfall events. Frogs were often tracked at night during heavy rains to ensure that they did not travel beyond our tracking range. We obtained each frog's exact location by walking toward the signal until we were able to see the frog, unless it was below ground. Locations were recorded with a GPS unit (Trimble GeoXM) accurate to within several meters. Finally, we used homemade single-ended funnel traps constructed of hardware cloth to capture frogs at their refugia; thus, we could remove the transmitters at the end of tracking. Traps were placed adjacent to refugia, and burlap was wrapped around the refugium so that the frogs would have to enter the trap when they emerged. Distances moved by frogs were measured from the center of the breeding pond.

Refugia Characteristics.—We recorded data on each frog's position (surface or underground) and vegetation characteristics around each summer refugium. Vegetation characteristics included (1) general habitat (upland longleaf pine, pine-hardwood, woody drainage, herbaceous drainage, field); (2) tree basal area (using a 10-factor prism); (3) canopy cover (using a convex densitometer); (4) percent of vegetation within a 1-m^2 area around each frog, wiregrass, leaf/needle litter, bare ground, other vegetation; and (5) type of refugium, mammal burrow, stump hole, or refugium dug by the frog (our site is not within the range of the Gopher Tortoise). Gopher Frogs maintain a small area adjacent to their refugium that is cleared of debris, exposing a "pad" of mineral soil (e.g., Richter et al., 2001). We recorded whether a maintained pad existed at a refugium the first day a frog was tracked to that location to determine whether the site had been occupied by a frog in the past.

Most stumps used for summer refugia were decayed to the point where only a ring of bark remained, with or without a standing section of heartwood in the center. We measured the maximum diameter of the base of the stump, either from bark to bark on the surface of the ground ($N = 4$) or the extent of discernable crater where the original stump had been ($N = 2$). We were unable to measure two stumps that were completely decayed. To estimate the sizes of the trees that produced the stumps used for refugia, we used the equation from a linear regression of the diameter at ground to diameter at breast height (Bylin, 1982) for the 10 living longleaf pines nearest to each refugium ($R^2 = 0.88$). We attempted to age stumps with obvious saw marks by obtaining timber sale records for the property.

Results

Post-breeding Movements.—We successfully tracked 17 Gopher Frogs away from the breeding pond (Fig. 1). Five were tracked in 2009 (Frog IDs 563, 338, 375, 203, 325), and 12 were tracked in 2010 (all others). Twelve tracked frogs were released the night they were captured and migrated away from the pond immediately; three were released the morning following being captured, and two were released at night after being held in the laboratory for seven days while we waited for transmitters. The five frogs that were released in the morning or held in the lab and released at night stayed within a few meters of their release location immediately outside of the drift fence until the next rainy night. We treated this movement as the first tracking day.

We tracked nine Gopher Frogs (five females and four males) to their final summer refugia. The remaining frogs (four males and four females) suffered belt failure, signal loss, or death (Table 1). We also documented the breeding and summer habitat locations for one frog in two consecutive years. Frogs were tracked for five days (a frog that was killed by fire) to 69 days (mean = 39 days). Final summer refugia were located 0.5–3.5 km from the breeding pond (mean ± SE = 1.3 km ± 0.30). Frogs that were not tracked to the final summer refugia ($N = 8$) traveled 0.3–1.8 km (mean ± SE = 1.0 km ± 0.19) away from the breeding pond.

Frogs made major migrations only on rainy nights, with few exceptions (four frogs shifted their locations by 5–22 m during dry weather and another moved 60 m during dry weather after being handled). Single-night migrations averaged 743 m and ranged from 263 m to 1.2 km. Thus, frogs were capable of migrating at a rate of 100 m/h measured from the release time to sunrise. Of the nine frogs that were tracked to their final summer refugia, five traveled directly to their refugium in a single night (the night they were captured and fitted with a transmitter), and their refugia ranged from 505 m to 1.2 km from the pond. The remaining four frogs took 9–27 days to reach their final refugia, encompassing between two and six different rainy nights; these frogs mostly traveled to refugia >1.4 km from the breeding pond (Table 1).

Gopher Frogs used a variety of refugia while they were migrating from the breeding pond to summer refugia. Two frogs used shallow small mammal burrows in fallow fields. We also observed two frogs that dug their own shallow holes while in transit. In these instances, a shallow, angled depression was excavated sufficient to cover the entire frog immediately below the surface. Three frogs used shallow holes of unknown origin while in transit to summer refugia. Although these small depressions were similar in size and shape to holes that were constructed by Gopher Frogs during this study, the absence of disturbed soil indicated that they had not been excavated recently. One frog sheltered in holes associated with the stumps

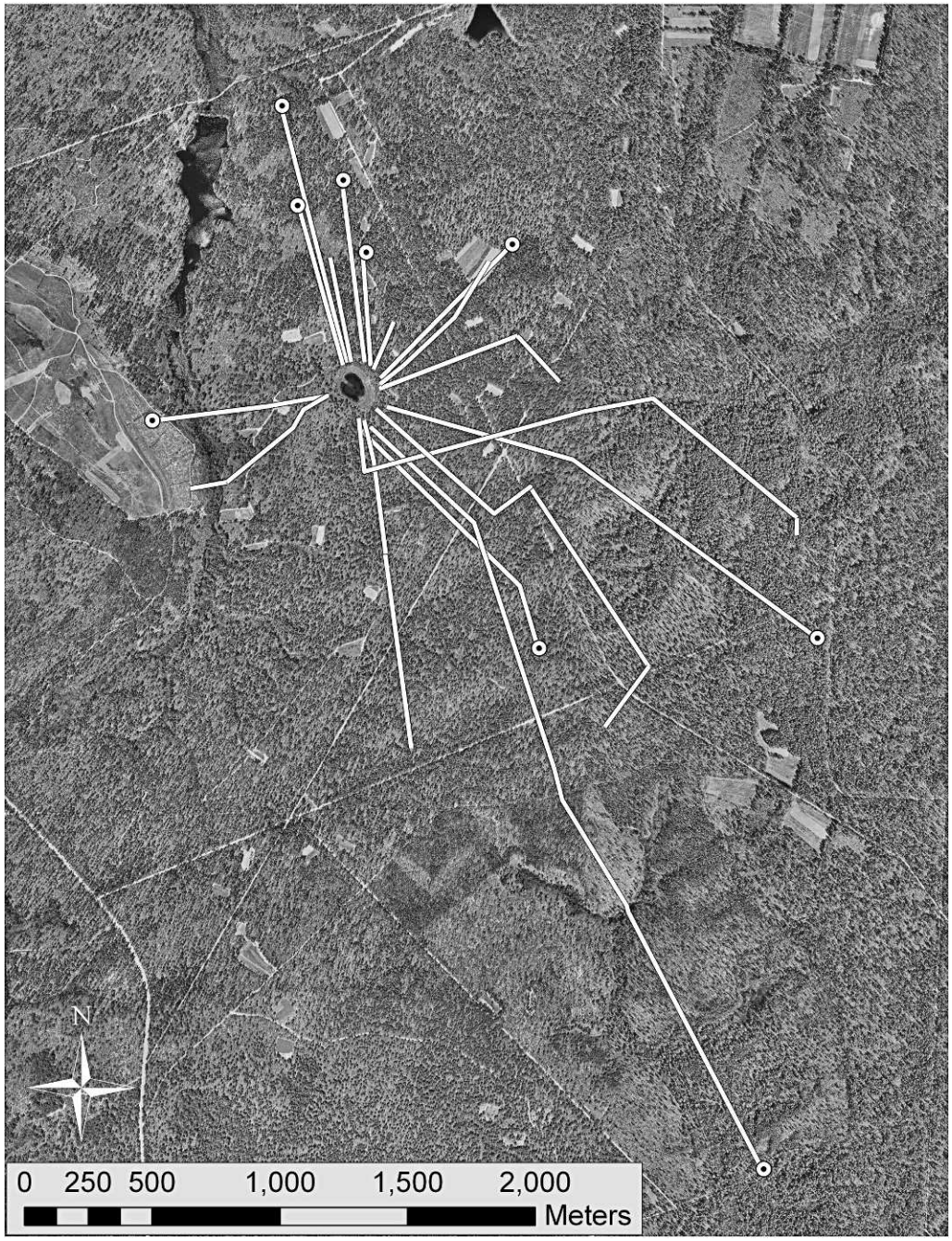

FIG. 1. Post-breeding movement patterns of 17 adult Gopher Frogs (*Lithobates capito*) from the breeding pond to uplands on the Sandhills Game Land, Scotland County, North Carolina. Circles at the end of frog paths represent animals that were tracked to their summer refugia. Frog paths without circles represent animals that were still traveling when their transmitter belt failed, their signal was lost, or they were killed. The area shown on this map represents 1,900 ha.

of oaks (*Quercus* sp.) on two separate occasions while traveling to a summer refugium.

Tracked frogs that did not make a single migration to a refugium ($N = 12$) spent an average of 12 days (range = 0–35) sitting on the surface during dry periods as they migrated (Table 1). Eleven of the 17 frogs (65%) we tracked sat exposed on the surface at least one day during migrations. In these instances, they were either completely exposed at the base of a clump of vegetation or situated just beneath leaf litter. Frogs were on the surface during March, April, and early May during migrations away from the breeding pond. All frogs successfully tracked to their summer refugia reached these protective refugia by early May.

Gopher Frogs in our study migrated through a variety of habitats including open longleaf pine forest, dense oak stands, and small fallow fields. Six telemetered frogs crossed small drainages that supported first-order streams surrounded by thick vegetation. The only barrier to migration appeared to be an impounded lake and an associated upstream beaver pond complex (Fig. 1, upper left). A very small proportion of frogs caught at the fence entered or left the pond from the direction of the lake, and the tracked frogs that traveled in that direction crossed the drainage just upstream from the open, standing

TABLE 1. Post-breeding movement patterns of Gopher Frogs (*Lithobates capito*) on the Sandhills Game Land, Scotland County, North Carolina, during 2009 and 2010. Dashes indicate unknown or nonapplicable data. "Surface" indicates frog was above ground and not associated with a refugium.

ID	Sex	Days tracked	No. of moves	Dist. moved from pond (m)	Days to reach summer refugium	Date at summer refugium	Latest known date on surface	Days on surface during travel	Fate
563	F	11	2	300	–	–	3 Apr	1	Killed by predator
129	F	67	1	505	1	13 Mar	–	0	Tracked to hole
902	M	5	1	524	–	–	9 Apr	4	Killed by fire
338	F	58	4	698	–	–	6 May	2	Lost signal
228	M	39	3	813	–	–	9 Apr	10	Belt failure
375	M	67	1	738	1	11 Apr	–	0	Tracked to hole
046	F	23	4	751	–	–	25 Apr	15	Belt failure
150	M	28	1	780	1	29 Mar	–	0	Tracked to hole
110	F	33	2	798	9	21 Mar	20 Mar	9	Tracked to hole
090	F	27	1	808	1	13 Mar	–	0	Tracked to hole
028	M	29	1	1,108	1	29 Mar	–	0	Tracked to hole
203	F	65	4	1,237	8	14 Apr	13 Apr	3	Tracked to hole
191	F	30	2	1,436	–	–	8 Mar	0	Belt failure
270	M	19	3	1,659	–	–	30 Mar	13	Belt failure
208	M	35	4	1,833	–	–	9 Apr	35	Belt failure
164	F	69	3	2,053	27	9 Apr	8 Mar	26	Tracked to hole
325	M	61	6	3,470	25	6 May	5 May	25	Tracked to hole

water associated with the beaver impoundment. The recently thinned forest to the east of the pond did not appear to have an effect on Gopher Frog movements. Four of our frogs traveled through the thinned area without changing course, and most of the frogs captured during drift fence studies entered and exited from the side of the pond that had recently been thinned.

Summer Refugia Habitat.—Eight of nine (89%) frogs tracked to their summer refugia used holes associated with tree stumps in longleaf pine stands (Table 2). The presence of saw marks indicated that three of these stumps were created during forestry operations; one stump was a short standing snag created by natural tree mortality, and the remaining four stumps had deteriorated sufficiently that their origin could not be determined. One frog used a large burrow created by an unknown animal in a sparsely vegetated, former military parachute drop zone. Although most frogs used stump holes, characteristics of the forest and vegetation around refugia varied widely among frogs (Table 2).

The mean diameter of the base of stumps used by frogs was 72.1 cm (range = 68.6–78.7). Estimates of the mean DBH of the former tree that left was 42.9 cm (range = 41.4–45.7). The holes associated with stumps and one mammal burrow that were used by Gopher Frogs were 5.1–17.8 cm (mean = 9.3) in diameter. We were unable to determine the year that several of the stumps were created during forestry operations; however, logging in these stands took place before 1994. The presence of sawed stumps in the stands indicates that longleaf pine stumps remain on the landscape for at least 16 yr and likely much longer.

Site fidelity was verified for one frog (325) that was captured at the breeding pond both seasons and returned to the same stump hole 3.5 km away from the pond during two consecutive summers. The frog was tracked to its hole the first year, returned to the breeding pond the following year, and was then trapped at the same hole later that summer. Additionally, the stump holes of five eight frogs tracked to stumps had previously maintained pads associated with them, indicating that they were likely used by Gopher Frogs recently.

When trapping frogs to remove transmitters, we captured several species sharing refugia with Gopher Frogs, including an adult Black Racer (*Coluber constrictor*), a subadult Red Corn Snake (*Pantherophis guttatus*), an adult Northern Pine Snake (*Pituophis melanoleucus melanoleucus*), and a Southern Toad (*Anaxyrus terrestris*). However, we did not document mortality of any frogs sharing refugia with snakes.

Vulnerability to Early Season Prescribed Fire.—A controlled burn was initiated on the morning of 13 April 2010 in an area that contained four telemetered frogs, the only time telemetered frogs were exposed to controlled burning. Two of the frogs were underground in stump holes, whereas the other two were on the surface—one beneath a small pile of oak leaves on a slope adjacent to a small stream (frog 046), and the other beneath mixed hardwood leaf litter near the head of a small, dry tributary (frog 902). The positions of all four frogs were verified immediately before the burn, and the condition of the frogs on the surface was monitored regularly as the fire approached. Frog 046 was exposed to a backing-fire that moved slowly through the sparse fuels associated with a scrub-oak habitat and was able to move 20 m into the nearby stream to escape the fire. The line of fire that passed over frog 902 was a light head-fire with an approximate flame length of 1 m. Immediately after the fire had moved past the frog's location. It was found burned and dead on the surface 45 cm from its prefire location. The frogs underground in stump holes survived the fire.

DISCUSSION

Post-breeding Movements.—The migration distances we observed for several Gopher Frogs are substantially longer than has been reported for Gopher Frogs in other areas (Carr, 1940; Franz et al., 1988; Richter et al., 2001; Roznik and Johnson, 2009a). It is unlikely that the longest observed movement of 3.5 km in our study was an outlier because, given our small sample size, it is unlikely that we tracked the longest-moving frog in the population. Additionally, recent drift fence studies conducted on the Sandhills Game Land documented six Gopher Frog adults at four different traps, located from 1.5–5.2 km from our study pond (R. Sutherland, pers. com.). The pond we studied is the only pond in the area that has recently supported successful Gopher Frog reproduction; thus, it is highly likely that all Gopher Frogs in the area originated from our study pond.

TABLE 2. Characteristics of final refugia locations of Gopher Frogs (*Lithobates capito*) tracked on the Sandhills Game Land, Scotland County, North Carolina, during 2009 and 2010. Dashes indicate data that could not be obtained accurately.

ID	Refugia type	Stump dia (cm)	Original tree dia (cm)	Hole dia (cm)	Basal area (m^2/ha)	Canopy cover (%)	Wire grass cover (%)	Leaf/ needle cover (%)	Bare soil (%)	Total veg cover (%)
028	Stump hole	–	–	12.7	27.7	90	40	90	0	45
129	Stump hole	71.1	42.4	8.9	16.1	84	5	95	2	5
150	Stump hole	71.1	42.4	5.7	23.0	65	80	80	0	90
090	Stump hole	78.7	45.7	10.2	23.0	84	10	80	10	15
164	Stump hole	68.6	41.4	5.1	9.1	76	0	5	10	90
325	Stump hole	–	–	7.6	16.1	62	10	50	20	30
203	Stump hole	71.1	42.4	5.1	18.3	86	60	30	0	65
375	Stump hole	–	–	10.2	20.8	92	5	90	0	10
110	Mammal burrow	–	–	17.8	0	0	0	0	70	30
	Mean (+ SE)	72.1 (1.7)	42.9 (0.7)	9.3 (1.4)	19.3 (2.9)	71.0 (9.5)	23.3 (9.8)	57.8 (12.6)	12.4 (7.6)	42.2 (10.9)

Because of the wide range in movement distances reported for Gopher Frogs at different sites, we caution against underestimating the minimal amount of habitat needed to support a given population. Semlitsch and Bodie (2003) suggested that "core areas" and buffer zones around wetlands aimed at preserving habitat for amphibians should encompass a diameter of approximately 340 m around each wetland. The maximum distances Gopher Frogs traveled away from the breeding pond in our study was more than 10 times the suggested core area and buffer zone protection distance. If we use the maximum movement of Gopher Frogs we tracked from the breeding pond to their summer refugia, an area of 3,739 ha would be needed to provide for Gopher Frog breeding and summer habitat. Even if we were to exclude the frog that moved the longest distance, the average movement (1.3 km) and the second longest movement (2.1 km) still suggest that a core area of 538 ha to 1,308 ha would be required to provide habitat for the majority of frogs in our study population. Suggested core areas by Semlitsch and Bodie (2003) would provide habitat for few, if any, frogs at our study site. The amount of terrestrial habitat needed to support a population of Gopher Frogs may vary depending on upland habitat characteristics, but our findings highlight the need for the protection of large blocks of unfragmented, well-managed habitat.

Summer Refugia Habitat.—The importance of stump holes for Gopher Frogs was reported by Richter et al. (2001), but other studies have found that Gopher Frogs use the burrows of gopher tortoises and pocket gophers in areas where those species occur (Blihovde, 2006; Roznik et al., 2009; Roznik and Johnson, 2009b). Where gopher tortoises or pocket gophers do not occur, or where their populations have severely declined, stump holes are the most commonly used underground refugia (i.e.., Richter et al., 2001; this study). The frogs we studied used mainly the remnants of large pine trees with at least 5-cm diameter holes at the base of the stump. Stump holes of this type in upland habitat are extremely rare in the North Carolina Sandhills. Specifically, the area around our study pond averaged three useable stump holes per 10 ha (unpubl. data). The abundance and distribution of refugia, including stump holes, on different landscapes may be a factor that influences migration distances and upland habitat needs. This highlights the need to maintain large stumps on managed landscapes. Vegetation characteristics varied widely among summer refugia locations, suggesting that frogs focused more on where a useable stump occurred rather than a specific habitat condition. However, most of our study area contained well-managed longleaf pine forest so habitat choice would be difficult to discern.

We found that Gopher Frogs will use the same stump year after year and are capable of returning to the same stump several kilometers away from the breeding pond. We documented one case of confirmed multiyear site fidelity to a summer refugium, where a frog traveled over 14 km, from a summer refugium, to the pond, and back over consecutive seasons (measured as straight line distances from pond to stump hole). Gopher Frogs clearly have a strong sense of their landscape given that they are able to navigate across such large areas of forest to find habitat features as specific as a single pine stump year after year.

Vulnerability to Early Season Prescribed Fire.—Literature about direct mortality of amphibians during prescribed burning is sparse and difficult to measure (for an overview , see Pilliod et al. 2003). Like many other endemic species of the southeastern Coastal Plain, Gopher Frogs are adapted to, and restricted to, upland pine forests that have historically been maintained predominantly by summer fire (Knapp et al., 2009). In our study, migrating Gopher Frogs were oftentimes using cover that is typically consumed by fire (wiregrass and leaf litter) and at a time when prescribed burning is often conducted. The death of a telemetered frog during a typical prescribed burn demonstrated the vulnerability of migrating Gopher Frogs to fire. Although one frog was able to escape into a stream, most Gopher Frogs were rarely near water during migrations. Also, the short distance (45 cm) moved by the frog that was killed in the prescribed fire suggests that, in cases of moderate fire intensity, Gopher Frogs may not be capable of attempting an escape. The potential for Gopher Frogs to escape prescribed fire is even more unlikely when strip-firing and spot-firing techniques are employed, because these methods result in two or more opposing lines of fire. It is plausible to assume that populations of Gopher Frogs that migrate shorter distances than we report here may be less vulnerable to mortality from prescribed fire. However, Richter et al. (2001) also noted that Gopher Frogs used clumps of grass and leaf litter for cover during post-breeding migrations in Mississippi where the longest recorded movement was 299 m. Because of the risk of direct mortality and the removal of vegetative cover as a result of fire, we recommend conducting prescribed fires between mid-May and early October when adult Gopher Frogs are unlikely to be on the surface. Although, summer fires could negatively impact recently transformed juveniles as they leave ponds in midsummer, the benefits of summer fire (e.g., maintaining open-canopy ponds; avoiding adult mortality) to the overall health of the population likely outweigh the occasional loss of juveniles, which already experience high natural mortality (Roznik and Johnson, 2009b).

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Literature Cited

Bailey, M. A. 1991. The dusky Gopher Frog in Alabama. Journal of the Alabama Academy of Sciences 62:28–34.

Blihovde, W. B. 2006. Terrestrial movements and upland habitat use of Gopher Frogs in central Florida. Southeastern Naturalist 5:265–276.

Braswell, A. L. 1993. Status Report on *Rana capito capito* Leconte, the Carolina Gopher Frog in North Carolina. Report to North Carolina Wildlife Resources Commission, Raleigh.

Bylin, C. V. 1982. Estimating dbh from Stump Diameter for 15 Southern Species. Research Note SO-286. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, LA.

Carr, A. E., Jr. 1940. A Contribution to the Herpetology of Florida. University of Florida Biological Publications Science Series. Volume 3. Number 1. University of Florida Press, Gainesville.

Franz, R. 1986. The Florida Gopher Frog and Florida Pine Snake as burrow associates of the gopher tortoise in northern Florida. *In* D. R. Jackson and R. J. Bryant (eds.), The Gopher Tortoise and its Community, pp. 16–20. Proceedings of the Fifth Annual Meeting of the Gopher Tortoise Council. Florida State Museum, Gainesville.

Franz, R., C. K. Dodd Jr., and C. Jones. 1988. Natural history notes: *Rana areolata aesopus* (Florida Gopher Frog). Movement. Herpetological Review 19:33.

Greenberg, C. H. 2001. Spatio-temporal dynamics of pond use and recruitment in Florida Gopher Frogs (*Rana capito aesopus*). Journal of Herpetology 35(1):74–85.

Jackson, D. R., and E. G. Milstrey. 1989. The fauna of Gopher Tortoise burrows. *In* J. E. Diemer, D. R. Jackson, J. L. Landers, J. N. Layne, and D. A. Wood (eds.), Gopher Tortoise Relocation Symposium Proceedings, pp. 86–98. Florida Game and Freshwater Fish Commission, Nongame Wildlife Program, Technical Report, Number 5, Tallahassee.

Knapp, E. E., B. L. Estes, and C. N. Skinner. 2009. Ecological effects of prescribed fire season: a literature review and synthesis for managers. General Technical Report PSW-GTR-224. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Lee, D. S. 1968. Herpetofauna associated with central Florida mammals. Herpetologica 24:83–84.

Moler, P. E., and R. Franz. 1987. Wildlife value of small, isolated wetlands in the southeastern coastal plain. *In* R. R. Odum, K. A. Riddleberger, and J. C. Ozier (eds.), Proceedings of the Third Annual Nongame and Endangered Wildlife Symposium, pp. 234–241. Georgia Department of Natural Resources, Atlanta.

Moulis, R. A. 1995. A Survey of Suitable Habitat in Southwestern Georgia for the Gopher Frog (*Rana capito* spp.), Striped Newt (*Notophthalmus pertriatus*), and Flatwoods Salamander (*Ambystoma cingulatum*). Report to the U.S. Fish and Wildlife Service, Jackson, MS.

Phillips, K. M. 1995. *Rana capito capito*, the Carolina Gopher Frog, in Southeast Georgia: Reproduction, Early Growth, Adult Movement Patterns, and Tadpole Fright Response. Unpubl. master's thesis, Georgia Southern University, Statesboro.

Pilliod, D. S., R. B. Bury, E. J. Hyde, C. A. Pearl, and P. S. Corn. 2003. Fire and amphibians in North America. Forest Ecology and Management 178 (2003):163–181.

Richter, S. C., J. E. Young, R. A. Seigel, and G. N. Johnson. 2001. Postbreeding movements of the dark Gopher Frog, *Rana sevosa* Goin and Netting: implications for conservation and management. Journal of Herpetology 35(2):316–321.

Roznik, E. A. 2007. Terrestrial Ecology of Juvenile and Adult Gopher Frogs (*Rana capito*). Unpubl. master's thesis, University of Florida, Gainesville.

Roznik, E. A., and S. A. Johnson. 2009a. Canopy closure and emigration by juvenile Gopher Frogs. Journal of Wildlife Management 73:260–268.

———. 2009b. Burrow use and survival by newly metamorphosed Gopher Frogs (*Rana capito*). Journal of Herpetology 43(3):431–437.

Roznik, E. A., S. A. Johnson, C. H. Greenberg, and G. W. Tanner. 2009. Terrestrial movements and habitat use of Gopher Frogs in longleaf pine forests: a comparative study of juveniles and adults. Forest Ecology and Management 259:187–194.

Semlitsch, R. D., and J. R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17(5):1219–1228.

Thurgate, N. Y., and J. H. K. Pechmann. 2007. Canopy closure, competition, and the endangered Dusky Gopher Frog. Journal of Wildlife Management 71(6):1845–1852.

USFWS (United States Fish and Wildlife Service). 2001. Endangered and threatened wildlife and plants; final rule to list the Mississippi Gopher Frog distinct population segment of the Dusky Gopher Frog as endangered. Federal Register 66:62993–63001.

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