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A TENNESSEE CONUNDRUM: THE GOPHER FROG AT ARNOLD AIR FORCE BASE

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ABSTRACT—The occurrence of a small isolated population of gopher frogs at Arnold Air Force Base (Arnold AFB) in Coffee County Tennessee was inferred from the collection of a single specimen on 12 July 1993. Despite continued searches, a second specimen was not forthcoming until almost four years later (1 March 1997). The collection of this latter specimen, found less than 1 km from the first specimen, rekindled interest in the distribution of the gopher frog in Tennessee and prompted an even more intensive and deliberate three-year survey (1998–2000) for breeding sites. The potential breeding sites were surveyed by daytime searches for egg masses, night-time and automated aural surveys of calling males, tadpole surveys, and establishment or maintenance of pit fall or funnel traps associated with drift fences. No evidence of gopher frog breeding activity was found by any of these survey methods, suggesting that if gopher frogs are extant at Arnold AFB, they are exceedingly rare, exceptionally secretive, or breed in an as yet undiscovered or under-surveyed wetland. These musings can not be discounted as mere hopes; calls resembling those of gopher frogs, though not recorded, were heard by several individuals during the survey period. Calls of the elusive gopher frog continue to be reported, the last made during May of 2002 when three biologists reported hearing four calls during a twenty-minute period.

Gopher frogs (*Rana capito*) are secretive amphibians that inhabit moist meadows, prairies, woodlands, and pine scrub habitats within the coastal plain ecosystems of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana (Altig and Lohoefener, 1983; Palis and Fischer, 1997). Suitable habitat for gopher frogs is decreasing, due in part to the intense logging and subsequent development of slash pine plantations in the longleaf pine region of the southeastern coastal states (Bailey, 1991). Throughout their range, gopher frog populations are threatened by habitat loss resulting from conversion of natural forests to pine plantations, destruction of breeding ponds, fire suppression, introduction of fish to breeding ponds, and road mortality (Bailey, 1991; Palis and Fischer, 1997).

Although a strong association exists between gopher frogs and the southeastern coastal plain upland longleaf pine (*Pinus palustris*) forests, at least two populations exist outside this region. Disjunct populations of *R. capito* have been reported in Shelby County, Alabama (Bailey, 1991) and Coffee County, Tennessee (Miller and Campbell, 1996). Logging and development are encroaching on the Shelby County, Alabama population; its survival is doubtful (M. Bailey; pers. comm., 1999). Here, we summarize what is known about the gopher frog in Tennessee, report the results of the most recent efforts to locate breeding sites, and comment on the status and potential threats to the survival of this population.

Only two individuals have been found in Tennessee and both of these were collected at Arnold AFB. The nearest known population (Shelby County, Alabama) is located more than 100 km south of Arnold AFB and is itself isolated from coastal populations by more than 100 km. Gopher frogs were discovered at Arnold AFB during an evening rainstorm on 12 July 1993 at Hills Chapel Road (Miller and Campbell, 1996). A single specimen was collected on that night (Fig. 1). Despite intensive searches nearly four years passed until a second specimen was found on 1 March 1997. This latter specimen (Fig. 2), a gravid female, was captured in a pitfall trap associated with a drift fence that encircled a small woodland pond located less than one km from the collection site of the first specimen. The discovery of a second gopher frog at Arnold AFB prompted the initiation of a three-year project designed to determine breeding sites, distribution, and relative abundance of the gopher frog at Arnold AFB.

MATERIALS AND METHODS

Four different survey techniques were used to search for reproductive activity of gopher frogs: 1) daytime searches for egg masses, 2) night-time and automated aural surveys for calling males, 3) establishment or maintenance of pit fall or funnel traps associated with drift fences, and 4) tadpole sampling.

Selection of Wetland Sites to be Surveyed—Gopher frogs breed in a variety of wetlands, including borrow pits, ditches, sinkholes, and cypress ponds, but breeding sites typically are characterized as circular to semicircular depressional wetlands dominated by graminaceous vegetation (Palis and Fischer, 1997). The wetlands at Arnold AFB are extensive (ca. 0.24 km^2, Wolfe, 1996; Fig. 3). Consequently, topographic and wetlands maps (Bingham and Winford, 1998) were used to narrow the search for potential breeding sites. Few graminoid-dominated wetlands occur at Arnold AFB. Notable exceptions include W 80, W 530, W 531 and several ponds associated with or near the airfield (W 505, 540, and 541). Because of their vegetative or physical characteristics or proximity to the sites where the gopher frogs were collected, the following wetlands were surveyed: Ws 17, 22, 25, 34, 80, 107, 113, 505, 514, 515, 517, 524, 525, 528, 529, 530, 531 539, 540, and 541 (Fig. 3). Most of the listed wetlands are ephemeral or semipermanent, generally filling by mid-winter, be-

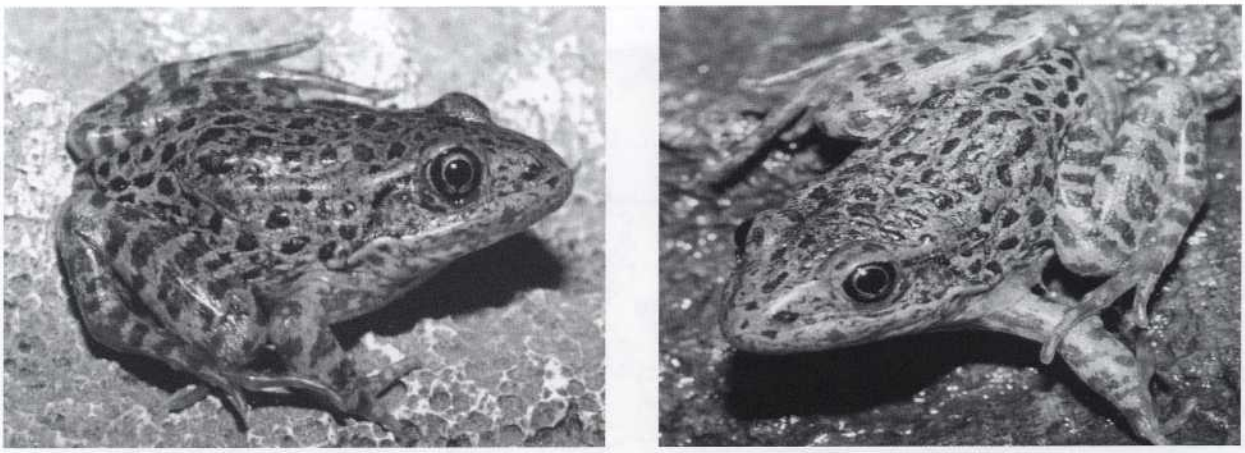

FIG. 1. Dorso-lateral and frontal view of juvenile gopher frog captured at Arnold Air Force Base.

ginning to dry during mid-spring, and are completely dry by early to mid summer. By late July or early August the larger wetlands, such as W 514 and W 538, are also dry. Surprisingly, several of the smaller wetlands (W 113, W 528, W 530, and W 531) hold water throughout much of the year and during some years they do not dry completely. The shape of the basin at each of these more permanent wetlands suggests that they have been artificially deepened. Regardless of the origin of the deeper basins, the greater permanence of these ponds has allowed predatory fish, such as sunfish (*Lepomis* sp.) to become established. Also, bullfrogs (*Rana catesbeiana*) are more abundant at the deeper basin ponds, such as W 530 and W 531, compared to the more natural wetlands (pers. obs.).

Timing of Reproduction—The breeding phenology of gopher frogs at Arnold AFB is unknown. The timing of reproduction at other localities varies from year to year (due in part to the association of breeding with rainfall). We assumed that breeding would most likely occur from February through early April because gopher frogs at Shelby County, Alabama generally breed during and following heavy rains during these months (Bailey, pers. comm., 1998).

Egg Mass Searches—Detection of egg masses is considered by most authorities to be the most efficient and reliable method to locate breeding sites (M. Bailey, pers. com. 1998; Palis and Fischer, 1997). Egg mass searches were conducted during the breeding season and entailed walking the perimeter of ponds deemed suitable for use as breeding sites and identifying amphibian egg masses found attached to vertical stems. Polarized sunglasses occasionally were used to help reduce the glare and, consequently, locate egg masses. Most of our egg mass survey was conducted during winter and spring, with limited survey work conducted during summer and fall (Table 1).

FIG. 2. Lateral view of adult female gopher frog captured at Arnold Air Force Base.

Calling Males—Automatic recording devices (frog loggers) were used to facilitate the detection of calling males and, thus, to increase the chances of locating breeding sites. Frog loggers were placed along the margins of select ponds, including W 530 (April 1999; mid-March through July 2000), W 113 (April 1999), W 531 (mid-March through July 2000), and W 541 (mid-March through July 2000).

Drift Fence—A drift fence encircling W 113 was used throughout the three-year study period. Small diameter pitfall traps, constructed from large vegetable tins, and funnel traps were used in conjunction with the drift fence during 1998 and the late winter and spring of 1999. A late December ice storm of 1998 toppled many trees onto the plastic fencing, rendering useless many sections of the fence. Consequently, not all amphibians were captured as they entered or left the pond during the winter or spring of 1999. None-the-less, enough of the fencing was intact to subsample amphibians during the late winter and early spring breeding migrations. The fallen trees were removed and the fence repaired by the autumn of 1999. Also, the funnel traps and vegetable tins used as pit fall traps were replaced with five-gallon buckets during autumn of 1999.

During the late summer, fall, and early winter of 1999, drift fencing and associated pits (using 3–5 gallon buckets) were placed around isolated sections of W 528 and W 530. Monitoring of W 113 was initiated in January and continued through June of 1999; monitoring was then resumed in October. W 528 and W 530 were monitored as fencing was established (during October at W 528 and November at W 530).

Tadpole Sampling—Tadpoles were sampled by dip netting during May and June of 1998, 1999, and 2000. Tadpoles identified in the field as green frogs (*Rana clamitans*) or bullfrogs (*Rana catesbeiana*) were released. Because of the difficulty in distinguishing between the tadpoles of southern leopard frogs (*Rana spenocephala*) and gopher frogs (Altig et al., 1998), many ranid tadpoles collected were reared through metamorphosis either in aquaria housed in a laboratory or confined in screened enclosures in natural wetlands.

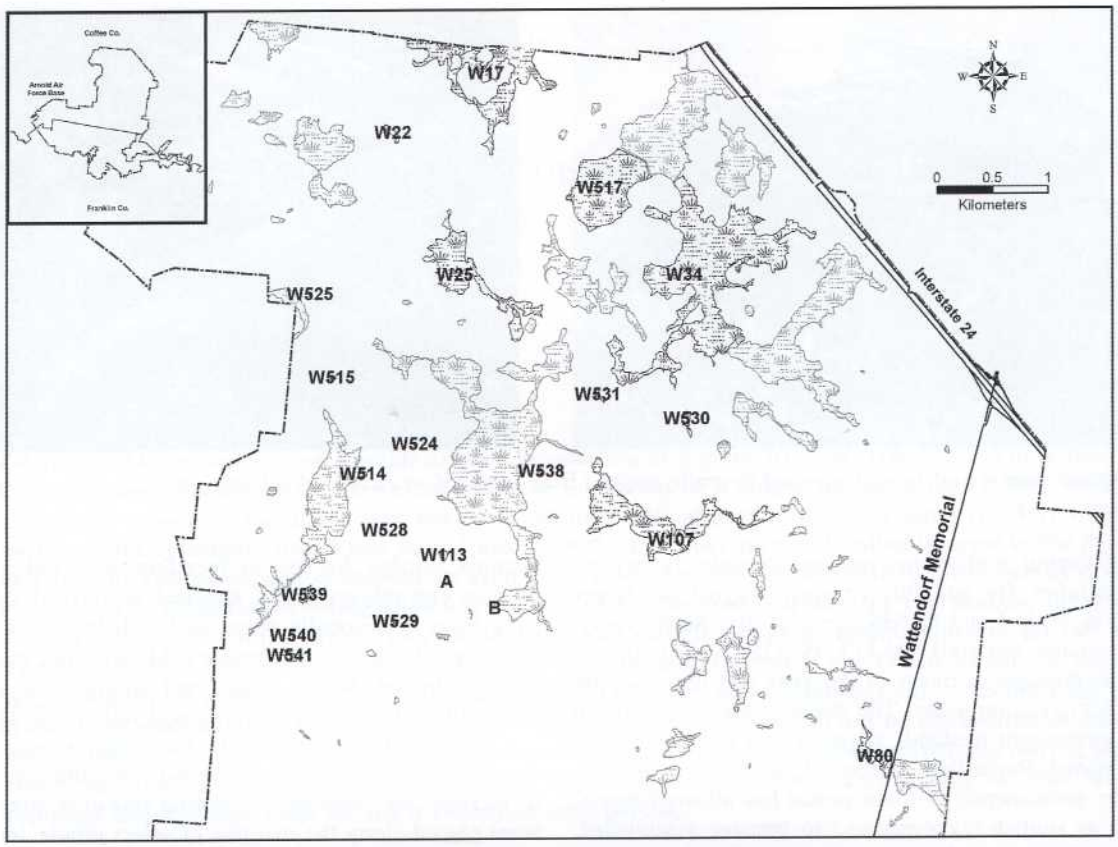

FIG. 3. The wetlands of the northern section of Arnold Air Force Base (AAFB). The location and boundaries of AAFB are provided in the inset. Wetland numbers follow those assigned in Atlas of Wetlands for AAFB by Bingham and Winford (1998). Only those wetlands surveyed for gopher frogs in this study are labeled. A. Designates the collection site of the juvenile gopher frog captured on 12 July 1993. B. Designates the collection site of the adult gopher frog captured on 1 March 1997.

RESULTS

Egg Mass Survey—No ranid egg masses were found that were identified as those of gopher frogs. However, on 16 March 1999, several egg masses containing early embryos that were noticeable larger than those typical of local *R. sphenocephala* were found in shallow water (approximately 9 cm in depth) along the western border of W 530. Voucher samples were collected and two egg masses were taken to the laboratory where they were reared through hatching. The hatchling tadpoles were distinctly larger than those of *R. sphenocephala.* None of the tadpoles survived through metamorphosis; therefore, positive identification was not possible. However, the hatchlings were smaller than those reported for gopher frogs at other sites.

Calling Males—No calls confirmed as those of gopher frogs were present on any of the frog logger recordings. However, calls resembling those of gopher frogs were reported by several individuals during the course of the study. Such calls were heard during early April 1998 in the vicinity of W 528 (Fig. 3; B. Miller, M. Fischer, pers ob.) and during early March 1999 at W 530 (B. Miller, pers. ob.). In each instance, the call was too brief to verify. Also, a call suspected to be that of a gopher frog was heard in the vicinity of W 600 on 29 June 2000 (M. Peterson, pers. comm., 2000).

Drift Fence and Pit Fall Trapping—No gopher frogs were captured in any of the funnel or pit fall traps during the study.

Tadpole Survey—No gopher frogs were identified from any of the tadpoles that transformed in the laboratory or outdoor enclosures.

DISCUSSION

The gopher frog is the rarest amphibian species at Arnold AFB; only two individuals have been collected during the last ten years and none during three years of intensive searching. The scarcity of gopher frogs contrasts markedly from the abundance of most of the other 25 amphibian species known to occur at Arnold AFB (Miller et al., in press). The only other species for which fewer than twenty individuals have been collected during the same time period is the tiger salamander (*Ambystoma tigrinum*); perhaps significantly, breeding sites of the tiger salamander also have not been discovered.

We do not know why breeding sites were not found. However, our inability to locate them suggests one, or a combination of, the following scenarios. 1) Breeding occurred in the wetlands searched, but the breeding population was so small that individuals avoided detection. 2) Breeding occurred, but at wetlands that we did not search or searched during a year that breeding did not take place. 3) Breeding occurred, but during the summer or fall, rather than winter or spring. 4) Breeding did not occur during the three years of study. 5) Populations are no longer extant.

We believe the gopher frog to be extant at Arnold AFB. The occasional unrecorded call heard during the three year study was recently augmented by three biologists working on an unrelated

TABLE 1. Summary of the field-work and laboratory work during the years 1998, 1999, and 2000.

Month	Number of days Year '98	'99	'00	Number of person hours Year '98	'99	'00
January	4	14	17	19.0	150.0	147.5
February	14	13	23	152.0	150.0	222.0
March	12	14	22	109.0	111.0	175.0
April	13	18	9	85.0	131.0	59.5
May	10	11	15	61.0	81.0	127.5
June	3	0	23	22.0	0.0	197.0
July	0	0	20	0.0	0.0	69.0
August	0	6	23	0.0	19.0	263.0
September	0	6	21	0.0	55.0	123.0
October	0	0	9	0.0	0.0	99.0
November	2	10	—	6.0	60.5	—
December	1	9	—	8.0	56.5	—
Totals	59	101	181	462.0	814.0	1482.5

project at Arnold AFB who reported hearing four gopher frog calls during a twenty minute period (J. Holmes, pers. com.). Very small populations of gopher frogs characterized by infrequent breeding have been reported in the Upper Coastal Plain of South Carolina (Semlitsch et al., 1995). Seven ponds were encircled with drift fences and intensively surveyed for several decades. Fewer than ten adults per pond were collected during any year. At some ponds, no more than a single adult was collected during a breeding season and several years separated the collection, and presumed reproductive activities, at several of the ponds. Hence, frequency of breeding is very low at these South Carolina Coastal Plain populations, but the populations are still extant. Certainly, the scarcity of gopher frog sightings suggests that a very small population exists. Possibly, infrequent breeding also characterizes the Arnold AFB population.

The breeding phenology and habitat requirements of gopher frogs at Arnold AFB potentially are very different from those reported as "typical" for gopher frogs (Palis and Fischer, 1997). For example, because of the emphasis that we placed on searching the wetlands during late winter and early spring, breeding activities that occurred during summer or fall could have gone undetected. Also, the expanse of the wetland area prevented us from searching all wetlands during each season and each year.

Although the occurrence of the gopher frog at Arnold AFB is a conundrum, their presence is likely associated with the complex hydric regime characteristic of the northeastern section of the base (Wolfe, 1996). Consequently, any alteration of the hydric regime resulting in modification of the surface flow and ground water movement could adversely affect potential gopher frog breeding sites, either by accelerating wetland drying or increasing the wetland permanence so that predators of gopher frogs, such as fish and bull frogs, become established. For example, sunfish (*Lepomis* sp.) were found at several of the large wetland systems, including W 514 and W 538 and at many of the small isolated wetlands, such as W 528 and W 530. The occurrence of predatory fish can render ponds unsuitable as breeding sites for gopher frogs (Palis and Fischer, 1997; NatureServe, 2000). Also, if the basins of these ponds have been artificially deepened, then they should be returned to a natural depth. By allowing the ponds to dry each year, populations of potential predators of gopher frog eggs and tadpoles, including invertebrates, fish, and bullfrogs, could be significantly reduced.

Lastly, reintroduction of gopher frogs to Arnold AFB should be avoided for several reasons. 1) Gopher frogs may still be extant. Although an adult has not been discovered since 1997, up to six years separated detection of gopher frogs at known breeding ponds in South Carolina (e.g., Ellington Bay, Semlitsch et al., 1995). 2) The systematics of gopher frogs is in a state of flux and the interrelationships of the different gopher frog taxa are unknown. The potential for the Tennessee population to be genetically distinct is great. Reintroduction would mask such a distinction. 3) The historical cause of the low density of gopher frogs is unknown. Reintroduced populations might suffer the same fate.

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