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Terrestrial Movements and Habitat Use of Gopher Frogs (Rana capito) at Fort Benning, Georgia

Jonathan H. Neufeldt
Columbus State University

TERRESTRIAL MOVEMENTS AND HABITAT USE OF GOPHER FROGS (*Rana capito*) AT FORT BENNING, GEORGIA

Jonathan H. Neufeldt

Columbus State University

The School of Science

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Terrestrial Movements and Habitat Use of Gopher Frogs (*Rana capito*) at Fort Benning, Georgia

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Jonathan H. Neufeldt

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Jonathan H. Neufeldt

We approve the thesis of Jonathan H. Neufeldt as presented here.

1 May '04
Date

Dr. William S. Birkhead, Professor and Chair of Biology, Thesis Advisor

11 MAY 2004
Date

Dr. James A. Gore, Professor and Head of Department of Environmental Science

Date

Dr. Julie Ballenger, Professor of Biology

ABSTRACT

Gopher frogs (*Rana capito*) were radio-tracked between the 2000 and 2001 breeding seasons to study their terrestrial movements and habitat use in a longleaf pine-sandhill area on the Fort Benning Military Reservation, Georgia. The telemetry research was conducted in response to the need for biological data concerning gopher frog terrestrial habits. Ultimately the data could aid biologists and land managers in describing critical habitat and the development of a management or recovery plan.

Twelve gopher frogs were caught at a herpetofaunal array surrounding two neighboring breeding ponds during a post breeding migration, implanted with miniature transmitters, released and radio-tracked one day per week. Data collected included: distances individuals moved between various locations, types of burrows used as refugia, general habitat descriptions, and extent of habitat use.

Results indicated that dispersal distances from the breeding site and distances moved between burrow locations varied a great deal between individuals, however all individuals but one stayed within 300m of the herp array surrounding the breeding site.

Burrows used by gopher frogs were either excavated by small mammal such as southeastern pocket gophers (*Geomys pinetis)* or old field mice (*Peromyscus polionotus*) or gopher tortoises (*Gopherus polyphemus*). Gopher tortoise burrows used were almost exclusively inactive or abandoned. All small mammal burrows used appeared to be inactive or abandoned.

Habitat types were delineated around the breeding site based on vegetation classifications and timber stand measurements. The total time spent by gopher frogs in delineated habitat types varied from 0 to 116 weekly observations. A positive linear

relationship was determined between number of gopher frogs known to use each habitat type, total number of burrows used in each habitat type and percent time gopher frogs spent in each habitat type. Gopher tortoise burrow density was negatively correlated with pine basal area and pine stem diameter, and positively correlated with hardwood basal area. Small mammal burrow density was negatively correlated with pine and hardwood basal area. The total number of observations at gopher tortoise burrows was positively correlated with hardwood stem diameter.

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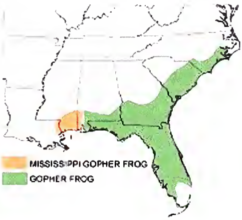
INTRODUCTION

The gopher frog (*Rana capito*) inhabits primarily xeric and mesic pine dominated flatwoods and sandhills in the southeastern Coastal Plain from North Carolina to Alabama. Two isolated populations occur north of the Coastal Plain Fall Line in Shelby County Alabama and Coffee County Tennessee (Fig. 1). Two species and three subspecies of gopher frog are presently recognized. Three subspecies of *Rana capito* are the Carolina gopher frog (*Rana capito capito*), Florida gopher frog (*Rana capito aesopus*) and dusky gopher frog (*Rana capito sevosa*). A genetically distinct population segment of the dusky gopher frog located on the Desoto National Forest, Mississippi was classified in 2001 as a second species and is known as the Mississippi gopher frog (*Rana capito sevosa*) (Fig. 1). The Mississippi gopher frog is the only federally listed gopher frog species. Although it has the same scientific name as the dusky gopher frog, the US Fish and Wildlife Service (USFWS) may eventually elevate it to *Rana sevosa*.



Map courtesy of Conservation South Inc.

Figure 1. Geographic Distribution of the Mississippi Gopher Frog (*Rana capito sevosa*) and the Gopher Frog (*Rana capito*)

The gopher frog is a stout, medium-large sized frog belonging to the family Ranidae ("true frogs") and genus *Rana*. Its weight may range from 18 to 76g for males and 40 to 82g (52 to 116g when gravid) for females, and snout-vent-length (SVL) may be from 57 to 94mm for males and 85 to 108mm for females (US Fish and Wildlife Service (USFWS) unpubl. data, 1998). The warty textured skin on the lateral and dorsal surface may vary in color from brown, gray-brown, brown-green to gray in color with dark brown or black spots, and the ventral surface is white or yellow-white with dark blotches (see Fig. 2).

Little is known about the gopher frog throughout much of its range. Its nocturnal foraging habits and short breeding season have restricted many studies to data collection during inventories at breeding sites in the winter and early spring. Initial quantitative data on the gopher frog were collected during population biology studies conducted at breeding ponds in southern Alabama (Bailey, 1990), South Carolina (Semlitsch *et al.*, 1995), southern Mississippi (Young and Seigal, 1994; Richter and Seigal, 1997), northwest Florida (Palis, 1998), and southwest Georgia (USFWS, unpubl., 2000).

Outside of the breeding season, information on terrestrial habits initially consisted of gopher frog observations in and near burrows of the gopher tortoise (*Gopherus polyphemus*) (Fig. 3a) (Franz, 1986; Bailey, 1991; USFWS, 1991; Palis and Fischer, 1997), crayfish, old field mice (*Peromyscus polionotus*) (Fig. 3b), and stumpholes (USFWS, 1991).

Much of the gopher frog research to date has been conducted on federal lands such as national forests, national wildlife refuges, one Department of Energy site (Savannah River Site) and several military installations. The Fort Benning Army Installation, GA contains a small population of gopher frogs located in a longleaf pine-sandhill ecological community.

Figure 2a. Dark Brown-Black

Figure 2b. Gray-Brown

Figure 2c. Green-Brown

Figure 2d. Gray with Yellow

Figure 2. Various Colors and Shades of Gopher Frogs (*Rana capito*) at Fort Benning

The USFWS focused its efforts on collecting gopher frog breeding population data at Fort Benning during annual inventories at two neighboring ephemeral ponds from 1996 to 2000.

Results from the inventories indicate that the two ponds may support the largest breeding population at a single breeding site in the state even though the overall population size at Fort Benning is probably not the largest (Jensen, Georgia Dept. of Nat. Res., pers. comm., 1999). Despite the large size of the localized breeding population, the gopher frog at Fort Benning is regarded as a species of conservation concern because of

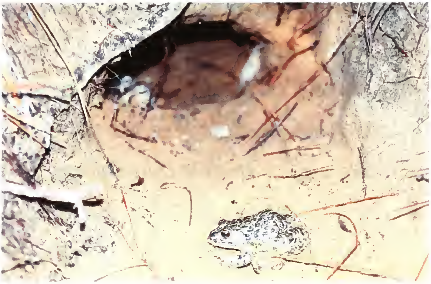


Figure 3a. Inactive Gopher Tortoise Burrow

Figure 3b. Inactive Old Field Mouse Burrow

Figure 3. Burrows Used as Refuge by Gopher Frog

its geographical isolation, limited breeding habitat, and the lack of information on its terrestrial habits (Andrews, USFWS, pers. comm., 1999). Furthermore, the Fort Benning gopher frog population was thought to have been an isolated population of the subspecies dusky gopher frog. The dusky gopher frog was a candidate for listing as threatened or endangered until 1996 when the status was withdrawn due to the lack of sufficient biological data describing non-breeding season activity (Andrews, pers. comm., 2000).

The annual gopher frog breeding season inventories at Ft. Benning were needed to learn about breeding migrations, demography, and aquatic habitat requirements. However, the inventories provided little information on terrestrial movements and habitat use during the non-breeding season. If the Fort Benning gopher frog were to regain its candidate species status and become listed like the Mississippi gopher frog, non-breeding season activity would be needed to aid in describing critical habitat and the development of a recovery plan as required by the Endangered Species Act (16 USC §§1531-1544).

Methods for collecting data on gopher frog movements and or habitat use include: observing gopher frogs crossing roads and trails while migrating to and from breeding sites during nighttime rain events, observing and or capturing gopher frogs at gopher tortoise burrows or breeding sites and radio-tracking individuals over a period of time. Only the latter can actually be used to determine movement and habitat use between consecutive locations over an extended period.

Since 1994, information on gopher frog terrestrial movements and habitat use has been collected with the aid of radio telemetry equipment. Studies conducted by Young and Siegel (1994), Phillips (1995), Richter and Siegel (1997), and Blihovde (pers. comm., 2000) indicate that radio-tracking is a feasible method of monitoring terrestrial movements and habitat use of gopher frogs. All four studies provided useful information on terrestrial movements, however they were not designed to investigate terrestrial range and habitat use during the entire period between consecutive breeding seasons. Since gopher frogs live a primarily terrestrial life, it may be useful to monitor radio-tagged individuals throughout the entire non-breeding season (including pre and post breeding migrations) in order to maximize data collection on terrestrial range and habitat use.

RESEARCH PROJECT OBJECTIVE

The objective of this study was to radio-track gopher frogs and determine their terrestrial movements and habitat use between the 2000 and 2001 breeding seasons on the Fort Benning Military Reservation, Georgia.

I made the assumption that gopher frogs would most likely use gopher tortoise burrows or some kind of small mammal burrow as refuge. I also assumed that the frogs would possibly select specific habitats that contain the burrow refuges. These assumptions would allow me to conduct a habitat use (preference) analysis or correlate habitat use (time spent in a particular type of habitat) with various habitat variables. I further assumed that individuals would most likely move between burrow locations during rain events since they are known to enter and leave breeding sites during rainy conditions.

MATERIALS AND METHODS

Project Site Description

Fort Benning is an 165,000-acre (66,775 ha.) army installation used for various types of military training, and is located in southwest Georgia in the upper Coastal Plain Physiographic Province along the Fall Line (see Fig. 4). The northeast portion of the installation contains an assemblage of ephemeral ponds. Two of these ponds were located next to each other (one natural and one artificial) and were used by gopher frogs presumably as a primary breeding site. The gopher frog breeding ponds were located in the K12 training compartment (northing 3596608, easting 719893 (UTM)) in the northeast portion of Fort Benning (see Fig. 5). The two ponds were surrounded by a herpetofaunal array (herp array) that was constructed by the USFWS in 1996 as part of an installation-wide wildlife inventory project. The herp array was a 921m long fence constructed out of 60.96 cm wide aluminum flashing that encompasses 1.86 ha, and was lined flush on the inside and outside with 16 pit-fall traps (18.93 l buckets) (see Fig. 6). Buckets on the inside and outside are lined up opposite of each other and are numerically labeled.

Gopher Frog Capture

As herpetofauna attempt to enter the ponds, they run into the flashing, follow the edge and fall into the pit-fall traps. The traps contained about an inch of water so that captured individuals did not dehydrate. Gopher frogs caught entering the array were marked with PIT tags (passive integrated transponder tags). The PIT tags were a little larger than a grain of long grain rice and contained a microchip with a 10 digit alphanumeric code, which was read with a handheld scanner. Each PIT tag was injected

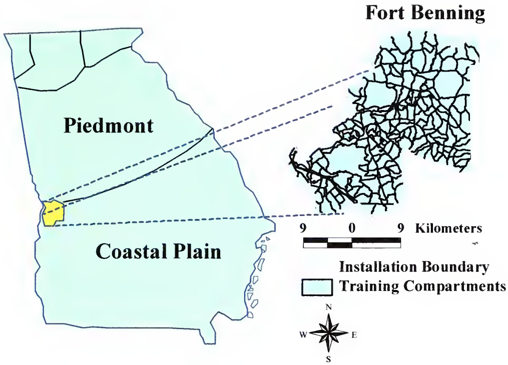


Figure 4. Map of Georgia Physiographic Provinces and Fort Benning

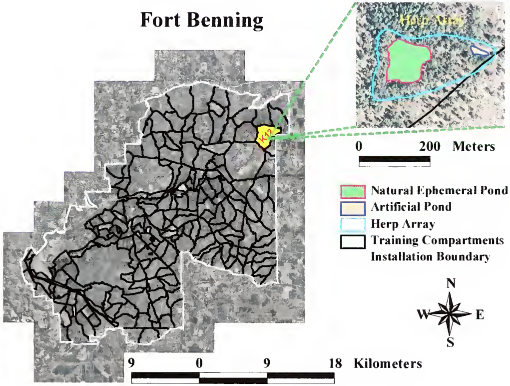


Figure 5. Aerial Photo of Fort Benning and Herp Array

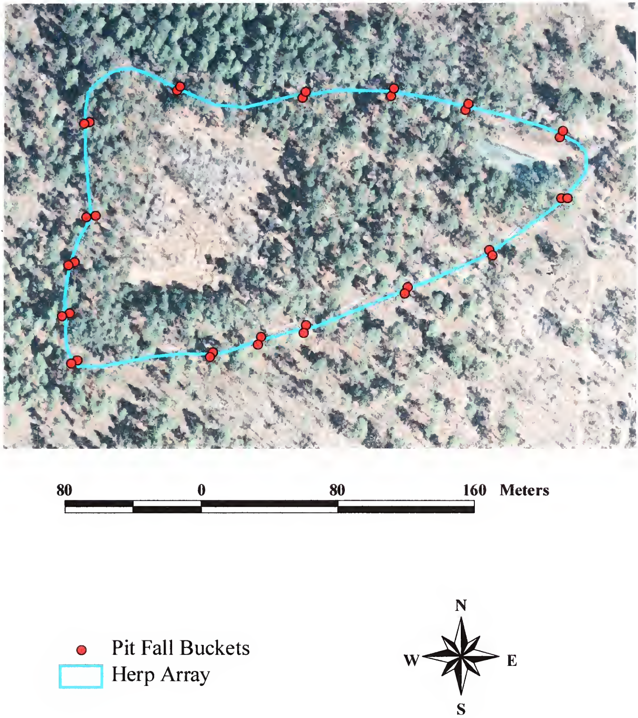


Figure 6. **Layout of K12 Herp Array**

into the peritoneum at the lower right ventral side of the individual.

During March 2000, 6 male and 6 female gopher frogs were selected for radio-tracking from the pool of individuals that were caught on the inside of the herp array after leaving the breeding ponds during a nighttime rain event. Local rain events are unpredictable therefore, it was important to choose radio-tracking candidates as early as possible.

Several pitfall buckets contained a proportion of the total number of gopher frogs caught exiting the array during a nighttime rain event. I used the proportion of total frogs caught per bucket to determine how many gopher frogs I would need to choose per bucket for radio-tracking. I did not select sexes based on proportions caught per bucket.

Criteria for choosing specific individuals for radio-tracking were that frogs had to have weighed ≥ 34 grams (i.e. transmitter weight could not be greater than 10% of the individuals body weight (Richards and Alford, 1994)) and frogs had to have appeared to be in healthy condition. All frogs were scanned for their PIT tag code, and information on sex, weight (g), and SVL (mm) was recorded.

Transmitter Implant Procedure

Each individual was transported to the Buena Vista Road Animal Hospital and implanted with a miniature transmitter by Dr. John Bloszies.

Each frog was anesthetized in a bath of 0.05% tricaine methanesulfonate (MS-222) and implanted with a sterilized inert resin encased single-stage miniature transmitter in the peritoneum (Appendix A). All frogs were initially implanted with transmitters (L.L. Electronics, IL) weighing 2.4 g (2.5 to 3 month longevity). After about three months, 9 of the 12 individuals were successfully caught and re-implanted with transmitters weighing 3.4 g (6 month estimated battery longevity). Two individuals were recaptured and implanted a third time with a 3.4g transmitter.

Internal transmitters were used because external packages use a whip antenna that can be caught on vegetation, prevent individuals from entering small burrows and could prove to be deadly (Madison, pers. comm., 1999). Richter (pers. comm., 1998) suggested using implanted transmitters because some gopher frogs in his study received skin abrasions from the external transmitter harnesses he used. Radio-tracking studies on American toads (*Bufo americanus*) (Werner, 1991), tiger salamanders (*Ambystoma tigrinum*) (Madison, 1997), spotted salamanders (*Ambystoma maculatum*) (Madison and Farrand, 1998), green frogs (*Rana clamitans*) (Lamoureux and Madison, 1999) and gopher frogs (Blihovde, pers. comm., 2000) were successful with the use of implanted transmitters.

Gopher Frog Release and Radio-tracking

Each radio-tagged frog was released within 24 hours after surgery during nocturnal hours outside the herp array directly opposite the site of capture. Individuals were initially radio-tracked five nights the first week, and twice the second and third week, once during the day and once at night. After three weeks, tracking was reduced to once a week. Individual gopher frogs were located and identified one time per tracking session to minimize over sampling. Tracking sessions were not limited to any one specific time during the day or night for two reasons. Firstly, radio-tracking was only done when the military was not conducting live fire training exercises at a nearby range. Secondly, almost all locations of individuals were at the mouth of or in burrows regardless of the time of day or night.

Locations of all individuals (locations meaning gopher tortoise or small mammal burrow entrances) were identified by direct location rather than triangulation. The transmission distance of the implanted transmitters ranged between 50 and 130m, making it possible to directly locate an individual once a signal was detected (i.e. the signal was followed directly to the location of the individual.). Signal strength varied depending on the density and structure of vegetation located between the receiver and the radio-tagged individual.

In order to ensure all radio signals came from live gopher frogs, attempts were made to visually observe individuals during dusk or at night by spotlighting burrow entrances. In the event a frog could not be visually identified, their position in the burrow was identified and recorded during each radio-tracking session during the day. The signals transmitted through the soil making them easy to pick up. The spot on the ground where the strongest signal reception occurred was marked with fluorescent orange pin flags each week. In all cases, locations inside burrows were different during each radio-tracking session suggesting that the frogs were indeed alive.

All locations were recorded and geospatially referenced using Global Positioning System (GPS) (Trimble Asset Surveyor) unit and mapped on digitized aerial photos (Tag Image File Format (TIFF) using Geographic Information System (GIS) software (ArcView 3.2) (Appendix B Fig. 1 - 12).

Habitat Description

Gopher frog terrestrial habitat was characterized by the vegetation present and the type and density of burrows that were potentially available as refuge. Habitat descriptions began with delineating the study area boundary after completing the radio-tracking portion of the project (Fig. 7). The study area was subdivided into seven smaller areas (Habitat I to VII) based on differences in basal area (BA) (m^2/ha) of over and mid-story pine (longleaf pine (*Pinus palustris*), loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*) and scrub-hardwood species (oaks (*Quercus spp.*), hawthorne (*Cretaegus flava*). The number of 25.4cm diameter at breast height (DBH) pine-hardwood stems/ha was recorded for each habitat type to indicate the presence of saw-timber size trees (i.e. the trees with the largest crowns and DBH). Basal area and DBH are both measurements that are commonly taken by wildlife and forest managers to delineate stands of timber or various forested wildlife habitats on Fort Benning. In this case, various basal areas and the number of trees that are saw-timber size or smaller in dbh determined the extent of canopy cover, which may have affected groundcover structure and distribution. Groundcover structure and distribution may influence the burrowing ability of gopher tortoises and small mammals, thus determining the presence or absence of potential gopher frog refuge.

Each habitat type was further described using the National Vegetation Classification Standard (NVCS) (Table 1). The NVCS is divided into physiognomic and floristic levels. The physiognomic level is subdivided into groups and formations, where the floristic level is subdivided into alliances and associations. Fort Benning is presently adopting the NVCS to help describe timber stands at a vegetation community level. I chose to use the NVCS to help describe gopher frog habitat.

The area of each habitat type was determined using ArcView 3.2 (Hutchinson and Daniel, 1997). Gopher tortoise burrow densities were calculated for each habitat type using burrow inventory data from the USFWS and surveys conducted by Columbus State

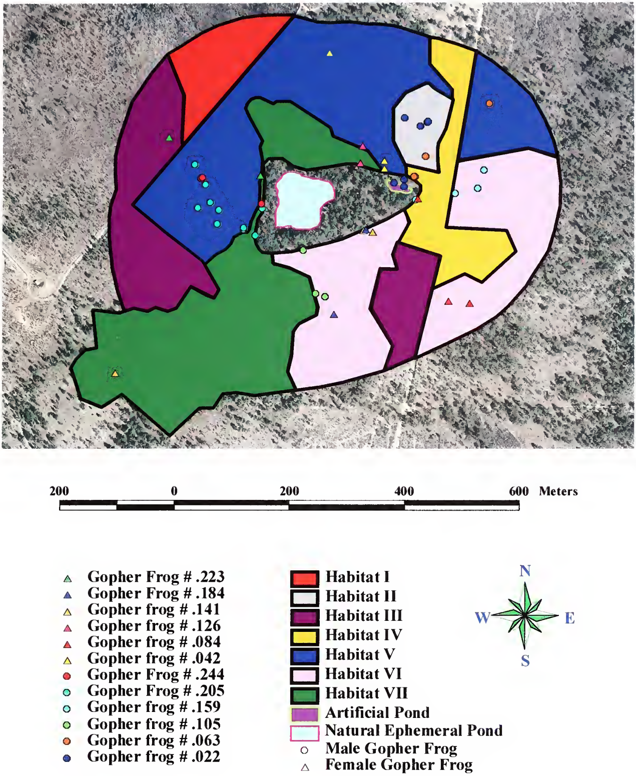


Figure 7. **Habitats I – VII and Corresponding Gopher Frog Locations**

Table 1. Description of Habitat Types I to VII (Area, Basal Area and NVCS Levels)

Habitat Type	Area (ha.)	Basal Area Range (m2/ha.)	Group	Formation	Alliance	Association
I	2.96	2.0 - 2.4	Other altered areas	Human impact	Military	Military
II	1.65	3.0 - 3.4	Other altered areas	Medium-tall sod, temperate or subpolar grassland	*Paspalm notatum* herbaceous	*Paspalm notatum* herbaceous
III	8.31	3.5 - 3.9	Longleaf pine sandhillls	Cold deciduous woodland	*Quercus laevis* woodland	*Cretaegus flava-Quercus (incana, laevis)/Quercus laevis (Andropogon virginicus, Aristida spp., schizachyrium scoparium)* woodland
IV	4.23	5.0 - 5.4	Longleaf pine sandhillls	Rounded-crowned temperate or subpolar -needle-leaved evergreen woodland	*Pinus palustris/Quercus spp.* woodland	*Pinus palustris-Pinus (echinata, taeda)/Quercus (marilandica, laevis)/Schizachyrium scoparium* woodland
V	16.07	7.0 - 7.4	Longleaf pine sandhillls	Rounded-crowned temperate or subpolar -needle-leaved evergreen woodland	*Pinus palustris/Quercus spp.* woodland	*Pinus palustris-Pinus (echinata, taeda)/Quercus (marilandica, laevis)/Schizachyrium scoparium* woodland
VI	12.2	9.5 - 9.9	Longleaf pine sandhillls	Rounded-crowned temperate or subpolar -needle-leaved evergreen woodland	*Pinus palustris/Quercus spp.* woodland	*Pinus palustris-Pinus (echinata, taeda)/Quercus (marilandica, laevis)/Schizachyrium scoparium* woodland
VII	14.29	14.5 - 14.9	Longleaf pine sandhillls	Rounded-crowned temperate or subpolar -needle-leaved evergreen woodland	*Pinus palustris/Quercus spp.* woodland	*Pinus palustris-Pinus (echinata. taeda)/Quercus (marilandica, laevis)/Schizachyrium scoparium* woodland

University biology students.

Small mammal burrow densities per habitat type were estimated by using a standard quadrat sampling technique (Elliott, 1977; Krebs, 1989). Three days of pre-sampling were devoted to determining the minimum quadrat size and number of quadrat samples needed to measure small mammal burrow densities. A total of ten 11 x 11m quadrats were determined to be needed and were randomly placed in each habitat type. Small mammal burrows were identified and counted within the quadrats and densities were estimated per habitat type.

Weather Data Collection

Gopher frog movement has been described as being correlated with rain events (Bailey, 1990; Palis, 1998). Most of the documentation is based on either observations of migrations to and from breeding sights, or breeding season inventories at breeding sites. Greenberg (2001) on the other hand determined that emigration of metamorphic juveniles from breeding sites was not correlated with rainfall. Because it was not certain whether gopher frog movement between radio-tracked locations might be correlated with rain event occurrence in the present study, data were collected to determine if individuals moved between locations during periods with no precipitation. All measurements of precipitation (mm) were recorded by an automated meteorological station located approximately 1km north by northeast of the study site. The meteorological station recorded precipitation amounts per 0.5 hrs. For the purpose of this project, rain events were defined as a single occurrence of continuous precipitation within a 0.5 hr. period. Discrete rain events were separated by at least 0.5 hrs of no precipitation.

Data Analyses

Descriptive statistics such as mean, standard error and range values were calculated for general measurements such as length, weight, distance, number of locations etc. Correlation analyses were calculated using SPSS Student Version 10.0 for Windows to help determine relationships between gopher frogs and their habitat (Cooper and Schindler, 2000).

Pearson's Correlation Coefficient was used to determine whether or not there was a significant relationship (H_O: $\rho = 0$ or H_A: $\rho \neq 0$) between the percent of total time gopher frogs spent in habitat types, total number of gopher frogs known to use each habitat type and total number of burrows used per habitat type (Zar, 1984). These variables were chosen to conduct a simple habitat use (or potential preference) analysis.

Spearman's Rank Correlation Method was used to determine if there was a significant correlation (H_O: $\rho = 0$ or H_A: $\rho \neq 0$) between gopher tortoise and small mammal burrow densities, total burrow density, total number of observations at gopher tortoise burrows, total number of observations at small mammal burrows, total number of observations at all burrows, mean pine BA, mean hardwood BA, mean total BA, mean number of pine stems $\geq$ 25.4 cm, mean number of hardwood stems $\geq$ 25.4 cm, and mean total number of stems $\geq$ 25.4 cm (Zar, 1984). These variables were chosen to relate typical forest management measurements with burrow type, density and length of burrow use.

Animals often do not or cannot eat when physical conditions are poor which results in weight loss and altered behavior. Since it was uncertain whether this was the difference in weight. Weight comparisons were determined by using the Wilcoxon Paired-Sample Ranks Test.

RESULTS

Gopher Frog Length and Weight Measurements

All 12 gopher frogs chosen for radio-tracking easily met the health, size and weight criteria. Length and weight measurements are presented in Table 2. The mean SVL was 88.17 $\pm$ 1.43mm and ranged from 79.00 to 94.00mm. The mean weight prior to the first surgery was 60.17 $\pm$ 2.22g and ranged from 46.00 to 74.00g. Weight measurements prior to the second surgery came from nine individuals because three were not recaptured. The mean weight prior to the second surgery was 54.11 $\pm$ 3.36g and ranged from 43.00 to 74.00g. Two individuals were re-captured and implanted a third time. The mean weight of the two gopher frogs was 55.60 $\pm$ 9.50g and ranged from 46.10 to 65.10g.

The first transmitter used weighed 2.40g, which was 4.05 $\pm$ 0.16% of the mean body weight of the frogs into which they were implanted, and ranged from 3.20 to 5.20. The second transmitter weighed 3.40g, which was 6.49 $\pm$ 0.36% of the mean body weight and ranged from 4.60 to 8.00%. The percent body weight of the third transmitter was 6.30 $\pm$ 1.10 and ranged from 5.20 to 7.40%.

Radio-tracking

Gopher frog locations and distances were tracked from March 2000 to March 2001 (Table 3, Appendix C.). The mean number of radio-tracked locations was 3.42 $\pm$ 1.05 with a range of 1 to 11. Gopher frogs .205, .159, and .022 were the only individuals that were radio-tracked back to burrows they were previously located. The mean shortest distance between two consecutive locations was 53.90m with a range of 2.30 to 212.40m. The mean longest distance between two consecutive locations was 191.84m with a range

Table 2. Gopher Frog Length and Weight Measurements

GF ID #	Sex	Snout to Vent Length (mm)	Weight (g) Prior to 1st Surgery	Weight (g) Prior to 2nd Surgery	Weight (g) Prior to 3rd Surgery	% Body Weight of 2.4g Transmitter Prior to 1st Surgery	% Body Weight of 3.4g Transmitter Prior to 2nd Surgery	% Body Weight of 3.4g Transmitter Prior to 3rd Surgery
0.184	F	94.00	74.00	-	-	3.20	-	-
0.126	F	92.00	61.00	-	-	3.90	-	-
0.042	F	92.00	59.00	-	-	4.10	-	-
0.084	F	93.00	62.00	67.00	-	3.90	5.07	-
0.141	F	83.00	58.00	51.00	-	4.10	6.70	-
0.223	F	91.00	67.00	74.00	-	3.60	4.60	-
0.244	M	87.00	60.00	53.00	-	4.00	6.50	-
0.063	M	93.00	67.00	49.00	-	3.60	7.00	-
0.159	M	86.00	58.00	45.00	-	4.10	7.50	-
0.105	M	83.00	46.00	53.00	-	5.20	6.50	-
0.205	M	85.00	62.00	52.00	65.10	3.90	6.50	5.20
0.022	M	79.00	48.00	43.00	46.10	5.00	8.00	7.40

Mean	88.17	60.17	54.11	55.60	4.05	6.49	6.30
Standard Error	1.43	2.22	3.36	9.50	0.16	0.36	1.10
Minimum	79.00	46.00	43.00	46.10	3.20	4.60	5.20
Maximum	94.00	74.00	74.00	65.10	5.20	8.00	7.40

GF ID # = Gopher frog identification number

Minimum = Smallest value of the range of measurements.

Maximum = Largest value of the range of measurements.

Table 3. Summary of Gopher Frog Radio-tracking Data (March 2000 - March 2001)

GF ID #	Total # of Days Tracked	Total # of Locations	Shortest Distance Between Two Consecutive Locations (m)	Longest Distance Between Two Consecutive Locations (m)	Shortest Distance From Location Released (m)	Longest Distance From Location Released (m)
0.141	78.00	2.00	19.04	618.20	19.04	598.90
0.126	81.00	1.00	40.54	40.54	40.54	40.54
0.042	27.00	2.00	19.63	256.30	19.63	270.53
0.084	215.00	2.00	44.50	225.40	224.51	246.79
0.184	54.00	1.00	188.25	188.25	188.25	188.25
0.223	94.00	1.00	212.40	212.40	212.40	212.40
0.244	233.00	2.00	4.24	140.70	138.99	141.53
0.205	344.00	11.00	4.20	128.50	29.38	197.58
0.159	89.00	4.00	38.10	81.20	85.79	157.31
0.105	215.00	2.00	20.20	94.40	96.30	112.88
0.063	194.00	2.00	53.42	172.00	53.42	222.63
0.022	348.00	11.00	2.30	144.20	110.94	127.22
Mean	164.33	3.42	53.90	191.84	101.60	209.71
Standard Error	31.72	1.05	20.38	42.77	21.58	39.84
Minimum	27.00	1.00	2.30	40.54	19.04	40.54
Maximum	348.00	11.00	212.40	618.20	224.51	598.90

"Total # of Locations" does not include locations where individuals were initially released.

of 40.54 to 618.20m. The mean shortest distance from location released was 101.60m with a range of 19.04 to 224.51m. The mean longest distance from location released was 209.71m with a range of 40.54 to 598.90m.

Throughout the course of the project, 11 of the 12 radio-tagged individuals eventually could not be located. Gopher frogs .184, .126, .159, .244, .105 and .042 disappeared without a trace. Transmitters from three individuals (.084, .223, and .063) were found outside near the entrance of the gopher tortoise burrows they were occupying. The transmitter to gopher frog .205 was found outside of the herp array near a pitfall bucket, where the transmitter to gopher frog .022 was found between the inside of the herp array and the artificial pond. Gopher frogs .205 and .022 were radio-tracked the entire non-breeding season. Gopher frog .022 was the only individual that was radio-tracked in one of the breeding ponds during the 2001 breeding season (Appendix B. Fig. 1).

Re-capture and Re-Implant

Nine of the twelve gopher frogs (.084, .141, .223, .244, .063, .159, .105, .205, and .022) were recaptured using Sherman box traps and re-implanted a second time, and two (.022 and .205) a third time. Gopher frogs .184, .126, and .159 were never recaptured. Gopher frog (.141) unfortunately died after being implanted a second time.

Habitat

The association level of the NVCS was the most descriptive of all the levels (see Table 1.). Habitat I is described as being part of the "military" association (i.e. military impact). Habitat II belongs to the *Paspalm notatum* herbaceous association. Habitat III belongs to the *Cretagus flava-Quercus* (*incana, laevis*)/*Quercus laevis* (*Andropogon virginicus, Aristida spp., schizachyrium scoparium*) woodland. Habitat IV to VII are part of the *Pinus palustris-Pinus* (*echinata, taeda*)/*Quercus* (*merilandica, laevis*)/*Schizachyrium scoparium* woodland association. Although four of the seven habitats belong to the same association, BA of over and mid story species is different.

Habitat measurements were split into two categories: burrow type used by individual gopher frogs (Table 4), and timber stands delineated by pine-hardwood over and mid-story BA (i.e. Habitat I to VII) and the amount of time spent by gopher frogs in each habitat type (Table 5 and Appendix D.).

Burrows selected were either originally excavated by gopher tortoises (*Gopherus polyphemus*) or some kind of small mammal. The small mammal burrows are thought to be from small rodents such as old field mice (*Peromyscus polionotus*) or southeastern pocket gophers (*Geomys pinetis*).

Gopher tortoise burrow entrance sizes varied to a degree but were all definitely excavated by adults. Small mammal burrow entrance sizes for the most part were not much bigger than the width of the gopher frogs.

Gopher tortoise burrows used were almost exclusively inactive or abandoned (abandonment defined as burrows that have been vertically altered/enhanced or partially collapsed or eroded). Only two active gopher tortoise burrows were used. The total number of inactive/abandoned gopher tortoise burrows used was 18. The mean number of inactive/abandoned gopher tortoise burrows used was 1.5 ± 0.19 with a range of 1.00 to 3.00.

The small mammal burrows used seemed to be inactive or abandoned based on

Table 4. Summary of Burrows Used By Individual Gopher Frogs

GF ID #	# of ACT GT Burrows Used	# of INA/AB GT Burrows Used	# of SM Burrows Used	Combined # of Burrows Used
0.141		1.00	1.00	2.00
0.126		1.00		1.00
0.042		1.00	1.00	2.00
0.084		1.00	1.00	2.00
0.184		1.00		1.00
0.223		1.00		1.00
0.244		1.00	1.00	2.00
0.205	2.00	3.00	3.00	8.00
0.159		2.00	1.00	3.00
0.105		2.00		2.00
0.063		2.00		2.00
0.022		2.00	2.00	4.00
Total	2.00	18.00	10.00	30.00
Mean	2.00	1.50	1.43	2.50
Standard Error	1.48×10^{-231}	0.19	0.30	0.56
Minimum	2.00	1.00	1.00	1.00
Maximum	2.00	3.00	3.00	8.00

GF ID # = Gopher Frog ID #
GT = Gopher Tortoise
SM = Small Mammal
ACT = Active
INA/AB = Inactive/Abandoned

Table 5. Basal Area Range For Each Habitat Type; Weekly Observations and Percent Time Spent Per Habitat Type

Habitat Type	Basal Area Range (m^2/ha)	Total # of Weekly Observations Per Habitat Type	% Time Spent in Each Habitat Type
I	2.0 - 2.4	0	0
II	3.0 - 3.4	43	15.03
III	3.5 - 3.9	14	4.9
IV	5.0 - 5.4	0	0
V	7.0 - 7.4	116	40.56
VI	9.5 - 9.9	96	33.57
VII	14.5 - 14.9	17	5.94

the lack of fresh aprons or non-maintained appearance. The total number of small mammal burrows used was 10 with a mean of 1.43 $\pm$ 0.30 and a range from 1.00 to 3.00. The total combined number of burrows used was 30.00 with a mean of 2.50 $\pm$ 0.56 and a range from 1 to 8.

The total amount of time spent by gopher frogs in each habitat type was measured as the total number of weekly observations of gopher frogs and percentage of time spent by gopher frogs in each habitat type. Habitat I and IV were not known to be used during the entire radio-tracking period. Habitats III and VII were used the least amount of time (14 and 17 weekly observations respectively). Total time spent in habitat II was moderate (43 weekly observations). Habitat V and VI were used the longest with 116 and 96 weekly observations respectively.

Weather Data

The total number of rain events that occurred during periods between all consecutive locations of gopher frogs was 122, with 59 occurring during the day and 63 at night (Table 6). Three of the 12 gopher frogs were found at only one location during the course of the study even though it rained a great deal. The other nine gopher frogs combined made 29 location changes. Five of the nine gopher frogs made 11 of the 29 location changes during periods without precipitation. Seven of eight successfully re-implanted gopher frogs made a combined total of eight location changes within one week or less after re-implant surgery. Five of the seven re-implanted gopher frogs moved during periods of no precipitation within 1 week after being re-implanted.

Correlation Analysis

The Pearson's Correlation Analyses revealed a highly positive linear relationship

Table 6. Summary of Rain Event Occurrences as They Relate to Gopher Frog Locations

GF ID #	Total # of Daytime Rain Events Between Consecutive Locations	Total # of Nighttime Rain Events Between Consecutive Locations	Total # of Rain Events Between Consecutive Locations	Total # of Location Changes With Only Daytime Rain Event Occurrances	Total # of Location Changes With Only Nighttime Rain Event Occurrances	Total # of Location Changes Without Rain Event Occurrances	# of Location Changes After Re-implant Surgery
0.141	2.00	4.00	6.00	0.00	0.00	0.00	Mortality
0.126	0.00	0.00	0.00	0.00	0.00	0.00	Not re-implanted
0.042	2.00	4.00	6.00	0.00	0.00	0.00	Not re-implanted
0.084	1.00	0.00	1.00	1.00	0.00	0.00	1.00
0.184	0.00	0.00	0.00	0.00	0.00	0.00	Not re-implanted
0.223	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.244	0.00	0.00	0.00	0.00	0.00	1.00	1.00
0.205	35.00	31.00	66.00	1.00	0.00	3.00	1.00
0.159	4.00	6.00	10.00	0.00	0.00	1.00	1.00
0.105	0.00	0.00	0.00	0.00	0.00	1.00	1.00
0.063	0.00	1.00	1.00	0.00	1.00	0.00	1.00
0.022	15.00	17.00	32.00	0.00	0.00	5.00	2.00
Total =	59.00	63.00	122.00	2.00	1.00	11.00	8.00

Consecutive locations are locations that were identified in successive order.

Gopher frogs 0.126, 0.184, and 0.223 used only one burrow during the radio-tracking period.

($\rho \leq 0.05$) (H_O is rejected) between total number of gopher frogs known to use each habitat type, total number of burrows used per habitat type and percent time gopher frogs spent in each habitat type (Appendix E).

Significant correlations ($\rho \leq 0.05$) (H_O is rejected) between forestry measurements and gopher frog burrow characteristics were: gopher tortoise burrow density is negatively correlated with mean pine BA and mean number of pine stems $\geq$ 25.4cm dbh, and positively correlated with mean hardwood BA; small mammal burrow density is negatively correlated with mean total BA; total burrow density is highly negatively correlated with mean total BA and total number of observations at gopher tortoise burrows is positively correlated with mean number of hardwood stems $\geq$ 25.4cm dbh (Appendix F).

Weight Comparison Analysis

The Wilcoxon Paired-Sample Signed Rank Test was used to compare gopher frog weights prior to the first surgery to weights prior to the second surgery (Appendix G). Results from the test indicate that weights prior to the first surgery are not significantly different from weights prior to the second surgery.

DISCUSSION AND CONCLUSIONS

Gopher Frog Length and Weight Measurements

The mean SVL and weight of gopher frogs on Fort Benning are different from populations elsewhere. The mean SVL of Fort Benning gopher frogs are 10% greater than Mississippi gopher frogs (Richter and Seigal, 1997) and 11% greater than central Florida individuals (Blohovde, 2000). Fort Benning individuals weighed 24% more than those Richter and Seigal (1997) radio-tracked in Mississippi. However, the mean weight of individuals radio-tracked by Blihovde (2000) in central Florida was 2% greater than of Fort Benning individuals. It is possible that the differences in weight and SVL measurements are due to small sample sizes. Another possibility is that gopher frog SVL is positively correlated with age. Franz (1986) determined from his gopher tortoise burrow associates-mark and recapture study in northern Florida that SVL was positively correlated with age. His results were based on weights and SVL measurements taken initially from sub-adults that were recaptured over a period of 16 months. The radio-tracked Mississippi gopher frogs may simply be younger than those from Fort Benning and central Florida and therefore were shorter. One could also speculate that genetics play a role in size differences between populations. The Mississippi gopher frog population has been determined to be genetically distinct from individuals sampled in Florida and Georgia. Samples from Fort Benning however were not taken. Comparing DNA from various populations including Fort Benning's may be useful to help determine if SVL/weight of adults is a genetic trait.

Radio-tracking

From March 2000 to March 2001 I successfully determined the terrestrial range and habitat use of gopher frogs on Fort Benning during the non-breeding season with the use of radio telemetry. I was not able to track all twelve radio-tagged gopher frogs during the entire non-breeding season however. The sample size grew progressively smaller because of individual transmitter signal loss, unsuccessful recapture attempts from burrows and mortality due to predation. I lost all but two individuals by the beginning of the 2002 breeding season. Had I used a larger sample size (e.g. radio-tagged at least twice as many gopher frogs) I could have possibly ended up with more gopher frogs throughout the entire non-breeding season, which would have increased the size of my data samples. Despite the small sample size of radio-tagged gopher frogs, I was still able to collect useful telemetry information.

All transmitters weighed less than 10% of the body weight of all individuals prior to initial and successive surgery. According to Richards *et al.* (1994), 10% of the body weight is the upper limit. Seigal (pers. comm.., 2001) suggested that the transmitter weight should be 5% or less. Typically, the smallest possible transmitter package would be best. Weight reduction can be accomplished by using a smaller battery in conjunction with reducing power consumption by slowing down the transmitter pulse rate, however I was not willing to potentially risk losing individuals due to a slow transmitting pulse. It is hard enough to pick up a faint pulse rate at one pulse per second because of signal obstruction by vegetation, the topography, because of a frog occupying a very deep burrow or because the frog was located 200m or more away from the receiver. Furthermore, the lightest transmitter available for wildlife telemetry at the time cost twice as much as the packages I used. More funding would have been necessary to purchase the lighter packages.

The length of time gopher frogs were tracked varied a great deal. Overall, males were tracked for a longer period than females. It is possible that the females that were eventually lost (lost meaning no signal was found and trapping attempts were not successful) had actually dispersed so far that the signal could not be detected, even during widespread systematic signal surveys. Whether females typically disperse further away from breeding sites than males is unknown. A larger sample size of radio-tagged individuals would probably be required to determine differences in post breeding migration distances between sexes.

Mortality certainly contributed to the overall length of tracking period for some individuals. One frog died after a second implant procedure, and five others most likely died due to predation (i.e. transmitters were found outside the body). The transmitters were still encapsulated by adhesive tissue. Since adhesive tissue is vascularized and forms around implanted transmitters (i.e. the transmitter is bound), there is no way for a transmitter to be expelled by a frog. It is more probable that the transmitters were spit out rather than ingested while the gopher frogs were being consumed. Furthermore, the presence of adhesive tissue on the transmitters suggests that predation was not by snakes. Snakes would have digested the adhesive tissue. Predation by raccoons (*Procyon lotor*) is more likely. Raccoons were known to periodically raid the herp array pitfall buckets and tracks were found in several gopher tortoise burrow aprons. Seigal (pers. comm.., 2001) suspected raccoons to have preyed upon individuals from the Mississippi population.

Recapturing and re-implanting gopher frogs increased the radio-tracking period. Gopher frogs were radio-tracked for a mean of 163 days. The length of time frogs were radio-tracked ranged from 27 to 348 days. This is well over the mean radio-tracking period of 52 days (range = 24 to 88) reported by Richter *et al.* (2001) and 60 days (range = 5 to 119) calculated from data presented in a master's thesis by Blihovde (2000).

The obvious advantage to radio-tracking for long periods is that it allows one to collect as much information as possible. For example, the mean number of radio-tracked locations (or known movements) documented on Fort Benning was 3.4 (range = 1 to 11). Richter et al. (2001) reported a mean of 2.3 with a range of 1 to 5. Blihovde (2000) did not report mean number of locations or movements. Overall, my recapture and re-implant methodology worked well enough to allow me to collect a decent amount of baseline information.

The average distance gopher frogs generally move from breeding sites is unknown. Most populations have not been studied and those that have been were based on small sample sizes. This is most definitely the case with my study. Nevertheless, even this minimal information is useful. Eleven of the twelve Fort Benning gopher frogs stayed within 300 meters of the location released, which is similar to what Richter and Seigal (1997) reported in their study. Blihovde (2000) did not report a maximum distance from the breeding pond in his study. The longest distance individual Fort Benning gopher frogs were found from the locations released ranged from 40.54 to 598.90m (mean = 209.71m). Richter and Seigal (1997) reported their frogs had ranged from 49 to 299m (mean = 173m) away from the center of the breeding pond. It is possible that some of Richter and Seigal's frogs were not able to move as far due to the external transmitters they used. The external antennas may have hindered movement by snagging on vegetation. This would make sense since only one out of twelve frogs in their study was known to use a burrow as refuge.

Single long movements between locations may occur primarily during migrations to and from the breeding site. The Fort Benning frogs that moved the longest distances did so within three weeks of initial release after breeding. Richter *et al.* (2001) found similar results. Blihovde (2000) reported the longest movement by his frogs was 90.00m while migrating to a breeding pond. This dispersal behavior, especially during post breeding migration, could be potentially useful to researchers or land managers if they needed to estimate the terrestrial range of gopher frogs for conservation purposes. Distances from breeding sites to refugia could be easily determined in minimal time (one month or less) through short-term radio-tracking.

Re-capture and Re-Implant

Individuals had to be recaptured from burrows in order to replace dead transmitters with new ones. Funnel traps similar to those used by Blihovde (2000) to capture frogs from gopher tortoise burrows did not work. However, Sherman box traps were used successfully to recapture frogs from small mammal and gopher tortoise burrows. I do not know why funnel traps did not work. Blihovde (2000) reported that it took several weeks to recapture some of his frogs with funnel traps. Perhaps gopher frogs actually see the funnel traps as an obstruction at the burrow entrance and shy away from it, where Sherman box traps may be viewed as part of the actual burrow.

Nine of the original twelve frogs were re-implanted a second time and two a third. With one exception of a single individual, second and third surgeries did not appear to affect the frogs any differently than the original surgery did. One individual died after the second surgery. Retrieval of the implanted transmitter was difficult because it migrated to a spot between the intestines and the back. Damage to the intestines while extracting the transmitter may have occurred, causing the mortality. Despite the mortality of one frog, re-implanting transmitters was successful. Conducting the implant surgery under sterile conditions by a veterinarian may have significantly contributed to the success.

Habitat

Gopher frogs are certainly not limited to using gopher tortoise burrows as refugia. One third of the burrows used were those of small mammals such as old field mice (*Peromyscus polionotus*) or southeastern pocket gophers (*Geomys pinetis*). The remaining burrows were those of gopher tortoises. Blihovde (2000) found that his frogs used both gopher tortoise and pocket gopher burrows. This may suggest that burrowing rodents such as pocket gophers and old field mice provide important supplemental refugia when gopher tortoise burrows are not available for occupation.

It is unclear whether gopher frogs actually select active gopher tortoise burrows or not. Franz (1986) observed gopher frogs using active gopher tortoise burrows more often than inactive ones during the course of his gopher-tortoise-burrow-associate study in northern Florida. Results from my study indicate that the radio-tagged individuals used inactive or abandoned gopher tortoise burrows almost exclusively. Only two of twenty gopher tortoise burrows used were active. These results contradict Franz's (1986), possibly due to differences in samples sizes. I only tracked the locations of twelve individuals where Franz (1986) monitored 72 burrows and marked 100 gopher frogs.

None of the small mammal burrows used on Fort Benning were active. Blihovde (2000) found similar results. Perhaps gopher frogs find it difficult to co-habit with small mammals due to the small size of the burrow.

The National Vegetation Classification Standard (NVCS) association levels may be a good general way of describing the landscape, however they need to be refined to quantitative levels that are of use to the forest and wildlife manager. I did not find the NVCS to be of use other than for general descriptions of habitat types. Quantitative information on plant species density, structure and distribution within a geo-referenced association would be useful for conducting correlation analyses.

Habitat I (altered area with overstory BA range of 2.0 to 2.4 m^2/ha.) and IV (longleaf-loblolly pine/scrub oak/little bluestem woodland with overstory BA range of 5.0 to 5.4 m^2/ha.) were not known to be used during the radio-tracking period. Habitat I is an area that has been negatively impacted by military disturbance, which may be the reason for low densities of burrows that could be used as refugia by frogs. Habitat IV contained potentially usable burrows, however none were used. It is possible that burrows or other refugia in habitat IV were simply never part of any one individuals terrestrial “home range” and were bypassed during the post breeding season migration.

The rest of the habitat types were used by the gopher frogs. The total amount of time spent by gopher frogs in habitats V (longleaf-loblolly pine/scrub oak/little bluestem woodland with overstory BA range of 7.0 to 7.4 m^2/ha.) and VI (longleaf-loblolly pine/scrub oak/little bluestem woodland with overstory BA range of 9.5 to 9.9 m^2/ha.) was greater than for any other habitat type(s). One could incorrectly interpret this as a sign of “habitat preference”. The Pearson’s Correlation Analysis (Appendix E. Tables 1 and 2) supports the habitat preference interpretation by indicating that the total time spent within a habitat type increased as the number of frogs and burrows used increased. The results however are based on pooled data from several individuals. Data per individual should also be analyzed and compared to compiled data in order fully interpret results. For example, gopher frog .205 used habitat V longer (41.3% of total time) than frogs .244 (30.2%), .063 (25%) and .042 (3.5%) did. Gopher frog .205 was radio-tracked longer (48 weeks) than any gopher frog in the study, which is the primary reason why habitat V was used the longest. Gopher frog .022 was radio-tracked the second longest time (41 weeks) and never left habitat II (altered area/bahaia grass-herbaceous groundcover with overstory BA range of 3.0 to 3.4 m^2/ha.) except when it migrated to the breeding pond. The percent time it spent in habitat II however was moderate when compared to the rest of the habitat types.

Habitats III (hawthorne-scruboak /broomsedge-little bluestem and threeawn grass with overstory BA range of 3.5 –3.9 m^2/ha.) and VII (longleaf-loblolly pine/scrub oak/little bluestem woodland with overstory BA range of 14.5 to 14.9 m^2/ha.) were used the least amount of time due to the mortality of gopher frogs .141 and .223. Gopher frog .126 used habitat VII exclusively but was radio-tracked for a short period and was never re-captured for implant replacement.

Perhaps more importantly is the correlation between number of burrows used and amount of time spent within a habitat type. Gopher frogs .205 and .022 were radio-tracked the longest and used the greatest number of burrows within a single habitat type. The positive correlation between amount of time spent in a habitat type and the number of burrows used may indicate that multiple burrow use is a key to survival.

It does appear that some gopher frogs show a preference towards using specific burrows. Burrow reoccupation occurred in the case of four individuals. Blihovde (2000) also found that some of his frogs reoccupied burrows, and Franz (1986) recaptured many individuals reusing the same gopher tortoise burrows. It would seem reasonable that once a gopher frog finds a burrow or assemblage of burrows that are available and the food source is adequate, it would not have any reason to move to a completely different area. Perhaps this site fidelity is initiated the first time a gopher frog leaves the breeding pond as a sub-adult and discovers a burrow. That would explain why the Fort Benning gopher frogs moved in a variety of directions away from breeding ponds rather than gravitating towards a specific area.

Weather Data

Gopher frog movement is often associated with rain events. Bailey (1990) and Richter *et al.* (2001) found a strong positive correlation between gopher frog movement and precipitation. Blihovde (2000) observed very little movement by gopher frogs at his study sites and attributed it to low rainfall. I was not able to positively relate movement with rain events even though most precipitation occurred during periods between consecutively radio-tracked locations. Radio-tracking sessions right before, during and after rain events were not logistically possible. Tracking gopher frog movement during or right after rain events could have been possible by setting up multiple telemetry receiver stations outfitted with automated data loggers near all of the gopher frog locations, however that would have required significantly more funding.

The majority of rain events (a total of 59 during the day and 63 at night) occurred during periods between consecutively radio-tracked locations. Three gopher frogs were observed occupying only one burrow during the course of the study despite the frequent number of rain events. It is unknown why they chose not to move. It is possible that they ended up reoccupying a "preferred" burrow (i.e. known safe refuge) that they were using prior to migrating to the breeding site.

Only eleven location changes occurred during periods without precipitation. Eight of the eleven location changes occurred within a week after re-capture and re-implant surgery. Six of the eight post surgery location changes occurred during periods without precipitation. Blihovde (2000) stated that some of his frogs might have moved because of disturbances from site visits and trapping. It is possible that some of the gopher frogs in my study moved to different locations during dry periods because of being captured and/or re-implanted. The only way I could have determined whether or not this was the case would have been to conduct a pre and post capture/surgery study.

Correlation Analysis

Pine BA and pine stems $\geq$ 25.4cm dbh were negatively correlated with gopher tortoise burrow densities. Gopher tortoises may not have been able to excavate burrows in high BA/large stem diameter pine stands because the herbaceous groundcover may have been too dense. However, mean gopher tortoise burrow densities were positively correlated with mean hardwood BA. Habitat containing many scrub hardwoods had very patchy groundcover and exposed soil. Conditions may have been optimal for good burrow excavation.

The total number of weekly observations of gopher frogs using gopher tortoise burrows was positively correlated with mean total number of hardwood stems $\geq$ 25.4cm dbh. I believe this to be a coincidence rather than a meaningful correlation because many gopher tortoise burrows were used where larger diameter hardwoods were not found.

The negative correlation between small mammal burrow density and total BA may be similar to the relationship between gopher tortoise burrow densities and pine BA. The groundcover (and root systems) may be too dense for small mammals to excavate burrows easily.

Weight Comparison Analysis

Significant weight loss by an animal is often an indication of a health problem and can lead to abnormal behavior such as lethargy or immobility (Bloszies, pers. comm., 2000). Blihovde (pers. comm., 2000) stated that several of his gopher frogs did not do well after he re-implanted them. I was not sure if implanted transmitters would possibly cause weight loss and affect normal behavior, so I compared weights of gopher frogs prior to the first implant surgery to weights prior to the second. I was not able to determine a relationship between individual weight loss or gain and the distance or the number of times an individual moved because it varied a great deal. Data analysis did indicate that the mean weight of all gopher frogs prior to the first surgery did not differ significantly from the weights prior to the second surgery. The frogs that lost weight however, were able to move various distances to multiple locations, rather than stay sedentary. This suggests that the transmitters probably did not interfere significantly with gopher frog movement behavior. The sterile surgical conditions in addition to the surgery being conducted by a veterinarian probably contributed to the seemingly healthy state of the implanted gopher frogs.

Conservation Measures

The Fort Benning gopher frog population was thought to have been an isolated population of the dusky gopher frog. The dusky gopher frog was a candidate species for listing as threatened or endangered until 1996 when the status was withdrawn due to the lack of sufficient biological data describing non-breeding season activity (Andrews, pers. comm., 2000). If the Fort Benning gopher frog were determined to be a distinct population segment of the dusky gopher frog, it could regain its candidate species status and become listed like the Mississippi gopher. In the event of being listed, biological data from this study would aid in describing critical habitat and the development of a recovery plan as required by the Endangered Species Act (16 USC §§1531-1544).

The Endangered Species Act of 1973 (amended 1988) in general describes critical habitat for listed species as: (1) the specific areas within the geographical areas occupied by the species, containing physical or biological features that are (a) essential to the conservation of the listed species and (b) which may need special management considerations or protection; and (2) specific places outside the geographic area that the species occupied at the time of being listed that are essential for the conservation of the species.

The Fort Benning gopher frog occurs in a unique longleaf pine –sandhill region of Fort Benning, and falls within the geographical range (coastal plain) occupied by all but two gopher frog populations. The primary physical features of the unique longleaf pine – sandhill region are the high concentrations of gopher tortoise and small mammal burrows located around the only known natural sandhill ephemeral pond on Fort Benning. The importance of the pond is its use as a "naturally occurring" breeding site by gopher frogs and should be protected.

The results of my study indicate that inactive small mammal burrows created by southeastern pocket gophers and old field mice in addition to primarily inactive gopher tortoise burrows are used specifically as refugia during the non-breeding season by the

Fort Benning gopher frogs. Gopher tortoises and small mammals therefore play an important role in gopher frog survival during the non-breeding season. Furthermore, gopher frogs prefer to occupy one or more specific burrows. The preferred use of specific burrows suggests strong site fidelity could be a common behavioral trait among gopher frogs. Interference with site fidelity through destruction of refugia could leave individuals vulnerable to predation. Firstly, an individual may actually expose itself to predation by staying in the area after the loss of refugia rather than immediately leaving to search for a new home. Secondly, predation may also occur during dispersal when searching for new refugia.

Information from my research should also aid in the development of a recovery plan in the event the Fort Benning and or other gopher frog populations were to be listed. The recovery plan should include "site-specific" management actions when necessary for the conservation and survival of the species. Site-specific management actions on Fort Benning would include practicing timber, fire and wildlife management techniques specific to the enhancement and maintenance of the unique longleaf pine-sandhill region containing both known and potential gopher frog habitat.

My research indicated that gopher tortoise burrow density was negatively correlated with pine BA. Small mammal burrow density was negatively correlated with total overstory BA. Habitat enhancement should therefore include reducing overstory pine BA in timber stands that are over stocked. The timber thinning would have to be compatible with management for the endangered red-cockaded woodpecker (*Picoides borealis*) (RCW). For example, RCWs survive and reproduce quite well in open, moderate BA pine stands (40 to 50 BA) that contain old growth pine trees. These open pine stands with moderate BA do support gopher tortoises in addition to other burrowing species that would provide appropriate refugia for gopher frogs.

A recovery plan would also need to state which timber harvest techniques should be used and avoided to minimize ground disturbance in areas that do or could contain gopher frog refugia. For example, a cut-to-length timber harvest method should always be used on soil very susceptible to ground disturbance because it will not compact the soil nearly as much as traditional feller bunchers, hydra-axes and skidders.

Results from my research indicated that gopher tortoise burrow densities are positively correlated with scrub-hardwood BA. Scrub-oak sites located near known gopher frog breeding ponds should not be converted to traditional pine plantations if they contain a large number of gopher tortoise and/or small mammal burrows. Site conversions usually call for the use of either roller-drum-chopping or herbicide. Roller-drum-chopping disturbs the soil more than any timber management practice and herbicides may have a residual toxic affect on gopher tortoises, small mammals and gopher frogs.

A recovery plan should contain a prescribed burn plan for maintaining or enhancing known or potential gopher frog habitat. Prescribed burning is by far the most cost effective and efficient method of managing the landscape. Burning rids the landscape of invasive fire intolerant vegetation, enhances patchy groundcover, and consumes dead and dying vegetation resulting in exposed patches of soil. The exposed patches of soil may be suitable for burrow excavation by gopher tortoises and small mammals resulting in potentially available gopher frog refugia.

Wildlife managers need to determine how much terrestrial gopher frog habitat to protect as part of a recovery plan. Unfortunately, distances gopher frogs migrate away from breeding sites may vary significantly, making it difficult to come up with a universal size in area to protect and manage. At Fort Benning, one could argue from the results of this study that land conservation efforts should extend at the very least 620 m or more from the breeding site. This distance represents the longest distance one gopher frog moved between two known locations. Another option would be to protect entire assemblages of potential breeding sites and surrounding terrestrial habitat. As long as site-specific management activities are properly conducted in designated critical habitat, gopher frog populations should continue to exist.

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Appendix A. Protocol for Surgically Implanting Miniature Transmitter

The following protocol was used for implanting transmitters in gopher frogs. The anesthetizing and surgical procedures were conducted in an "assembly line" fashion. Each frog was at a different stage of each procedure so that once surgery was finished with one frog, another frog was ready to be implanted.

Anesthetizing Procedure

- Dissolve 0.5g MS-222 in 500ml of room temperature distilled water.
- Check the pH with either a pH meter or pH indicator strips.
- The solution will be acidic (around pH 5.5) and should be buffered with a saturated solution of distilled water and sodium bicarbonate.
- Titrate buffering solution (drop by drop) until the MS-222 solution reaches a pH of about 7.0.
- Fill a sandwich ziplock baggy 1/3 full with the MS-222 solution.
- Put a gopher frog into the baggy. Hold the bottom of the baggy with one hand and keep the top of the baggy closed with the other hand just enough to allow for air to pass through without the gopher frog being able to escape.
- Squeeze the bottom of the baggy enough to displace the solution of MS-222 (i.e. squeezing the baggy will raise the level of the solution) so that the body of the gopher frog from the base of the head downward is submerged. The idea is to maximize the exposure of frogs skin to the MS-222 without preventing it from breathing.
- The gopher frog will eventually start thrashing around, indicating that it is about to succumb to the anesthetic. It may take several minutes (typically 4 to 8 minutes) for the frog to become anesthetized.
- Once the frog stops thrashing around, take it out of the baggy and set it on a towel dampened with water so it can be prepped it for surgery.

Surgical Procedure

- Sterilize a waterproof transmitter by submerging it in 2% chlorhexidine gluconate solution for at least 20 minutes. This can be done prior to the anesthetizing procedure. Make sure the transmitter is functioning before and after the sterilization process.
- Place anesthetized gopher frog ventral side up on a towel dampened with distilled water.
- Put on sterile surgical gloves and sterilize the entire ventral surface of the frog's body by gently scrubbing it (in small circular motions) with 2x2 in. gauze pads saturated with 4% chlorhexidine gluconate solution. Repeat this procedure two more times.
- Make an incision through the skin on the lower right or left side (in my case the left side) of and parallel to the midline of the ventral surface of the frog. Pull up the skin with forceps while cutting (this is called tenting) and be sure not to cut the vein running down the length of the midline. Make the incision just long

Appendix A. Continued

- enough to slip the miniature transmitter through. Make the same type of incision through the muscle wall without puncturing the internal organs (tent the muscle when cutting through).
- After taking the transmitter out of the cold sterile solution, rinse it off with sterile lactated ringers (without dextrose). Gently place the transmitter into the peritoneum.
- Suture the incision in the muscle with 5-0-size PDS suturing material with a cutting needle. Bury the sutures as much as possible in the muscle.
- Use the same suture material and needle to close up the incision in the skin. The skin is very tough and is comparable to that of a small iguana.
- After closing up both incisions, place the frog ventral side down on a towel and pour distilled water over it to rinse off any residual MS-222.
- Place the gopher frog on a damp towel in a plastic container with holes in the lid. Recovery from anesthesia will vary per individual. Full recovery from anesthesia is indicated by the individual being alert and sitting up.

Re-implant Procedure

- Follow the aforementioned procedures up to the point where the incisions are made.
- Spread the skin and muscle apart at the incision to see where the old transmitter is. If it migrated beneath organs, do not go digging for it. Instead, push in the sides of the frog to move the transmitter so it can be extracted. Pull out the transmitter with a pair of forceps, being careful not to perforate any organs.
- The transmitter will be encapsulated by vascularized adhesive tissue. Cut a slit into the adhesive tissue and pull out the transmitter. Place the tissue back inside the frog.
- If the vein leading to the adhesive tissue is accidentally cut or torn, tie it off with suturing material. Place the tied off vein and any tissue connecting to it back into the frog.
- Suture the incisions and begin post surgery recovery as mentioned earlier.

Appendix B. Mapped Locations of Radio-tagged Gopher Frogs

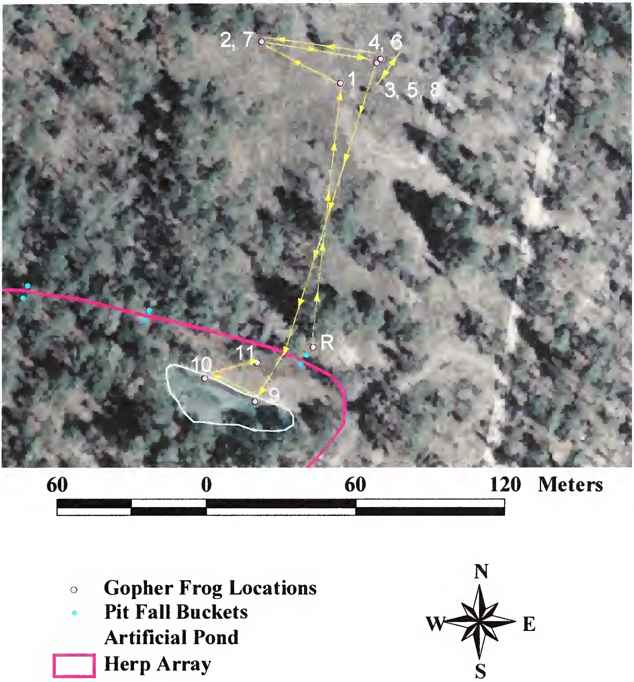

Figure 1. **Radio-tracked Locations of Male Gopher Frog #0.022**

Appendix B. Continued

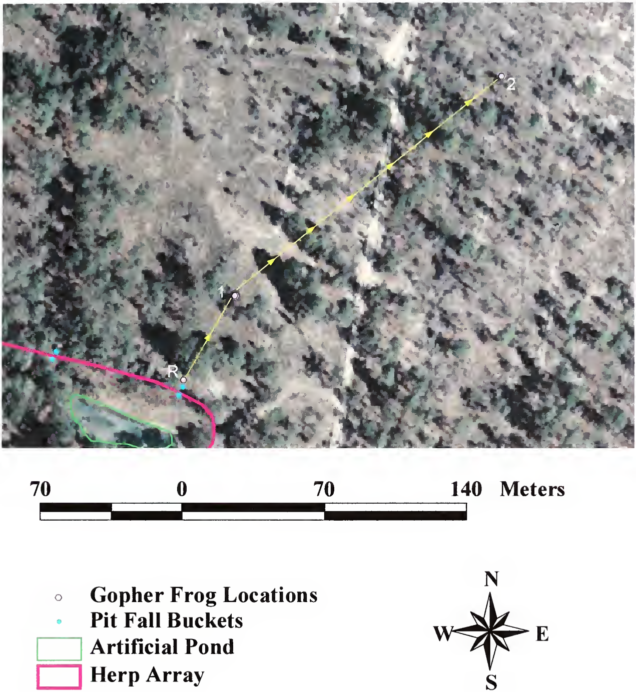

Figure 2. **Radio-tracked Locations of Male Gopher Frog #0.063**

Appendix B. Continued

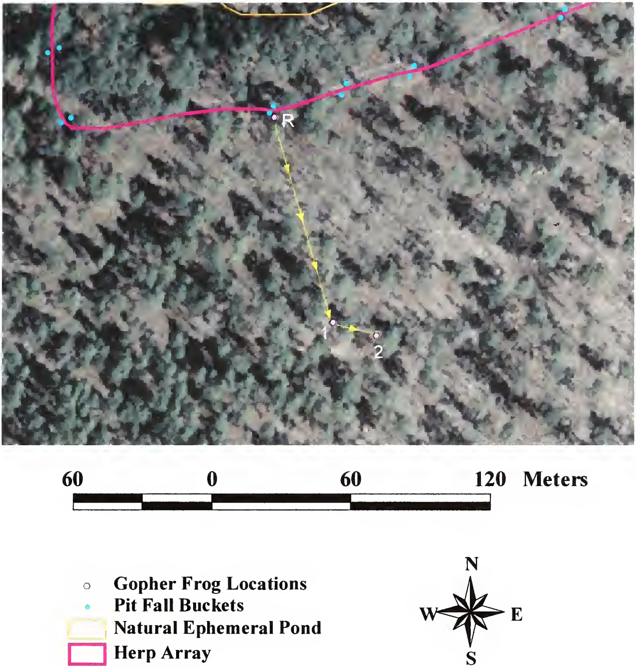

Figure 3. **Radio-tracked Locations of Male Gopher Frog #0.105**

Appendix B. Continued

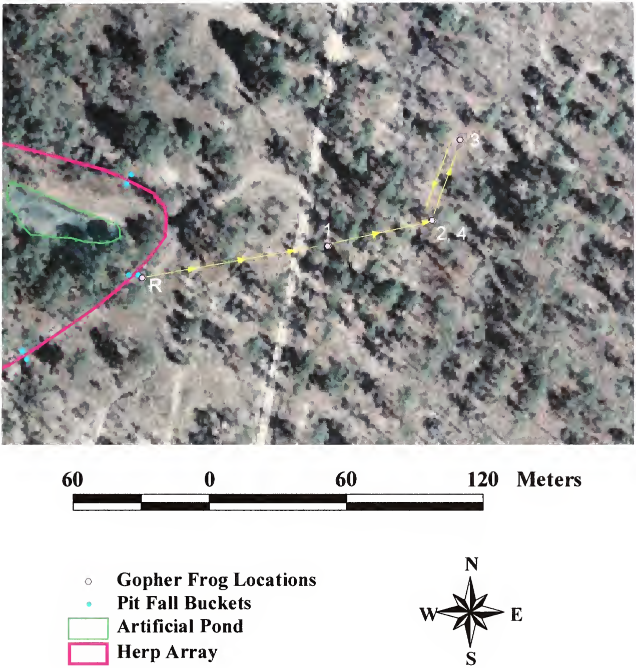

Figure 4. Radio-tracked Locations of Male Gopher Frog #0.159

Appendix B. Continued

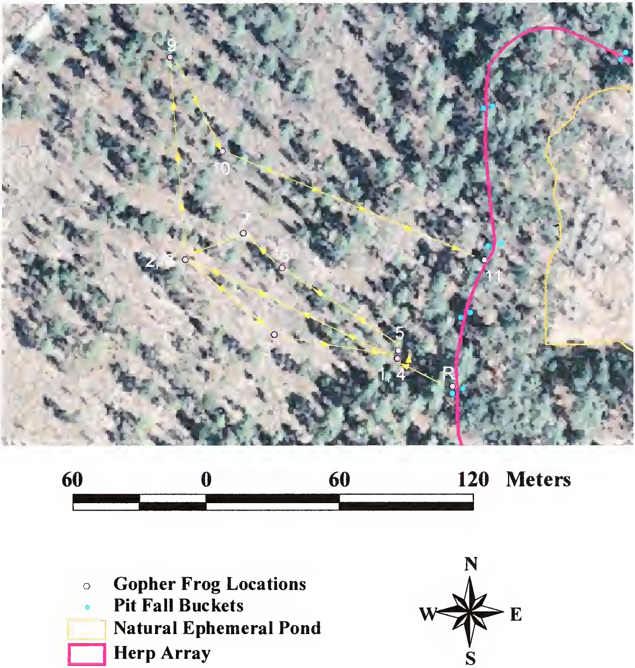

Figure 5. **Radio-tracked Locations of Male Gopher Frog #0.205**

Appendix B. Continued

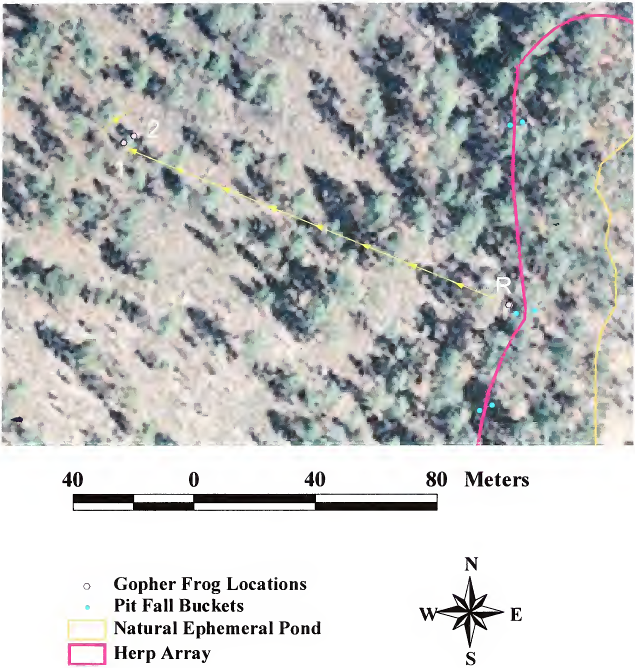

Figure 6. Radio-tracked Locations of Male Gopher Frog #0.244

Appendix B. continued

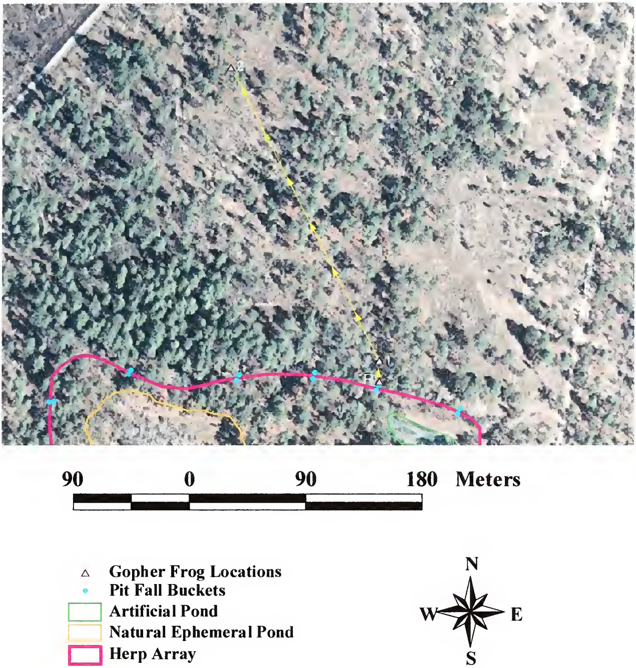

Figure 7. Radio-tracked Locations of Female Gopher Frog #0.042

Appendix B. Continued

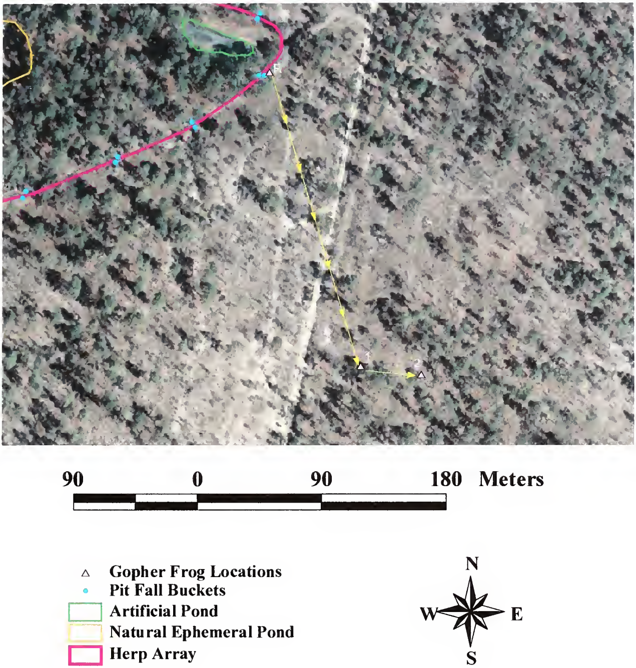

Figure 8. Radio-tracked Locations of Female Gopher Frog #0.084

Appendix B. Continued

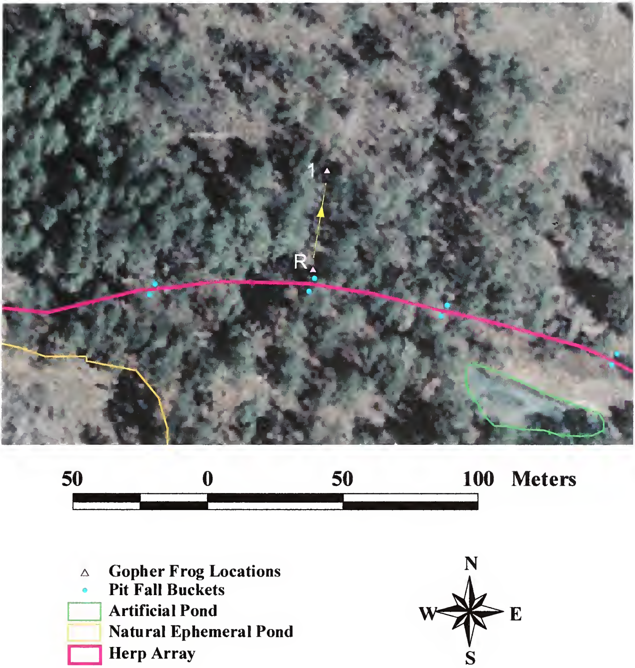

Figure 9. Radio-tracked Locations of Female Gopher Frog # 0.126

Appendix B. Continued

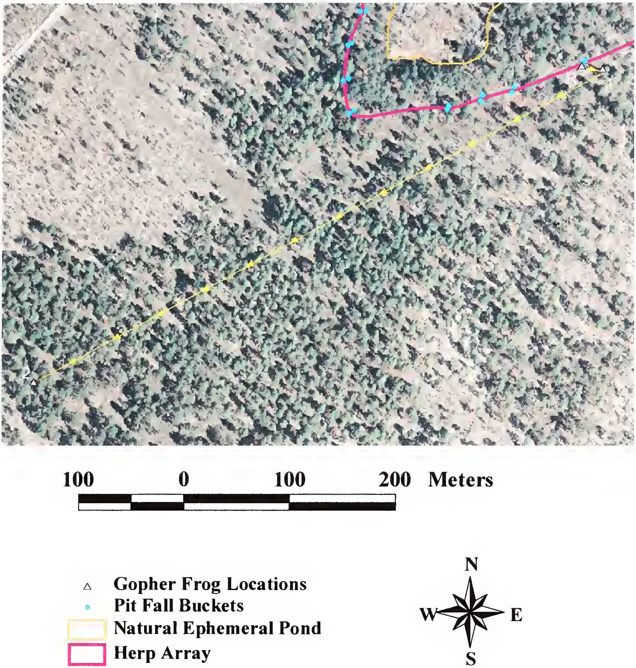

Figure 10. **Radio-tracked Locations of Female Gopher Frog # 0.141**

Appendix B. Continued

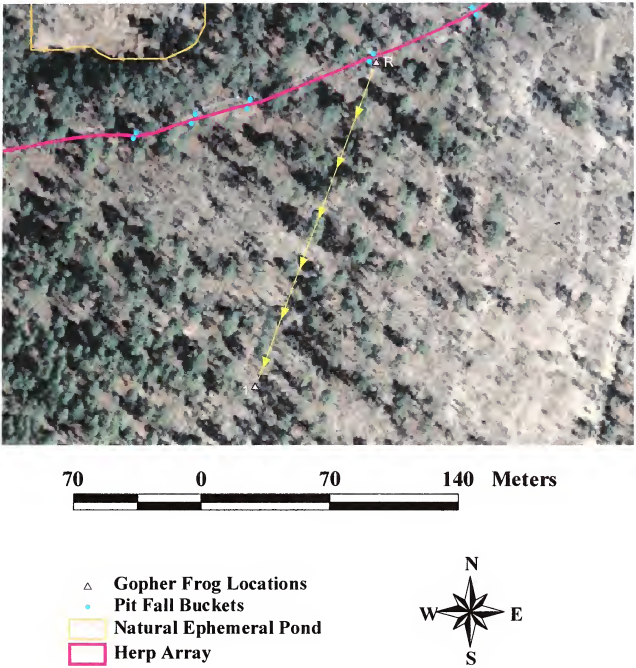

Figure 11. Radio-tracked Locations of Female Gopher Frog # 0.184

Appendix B. Continued

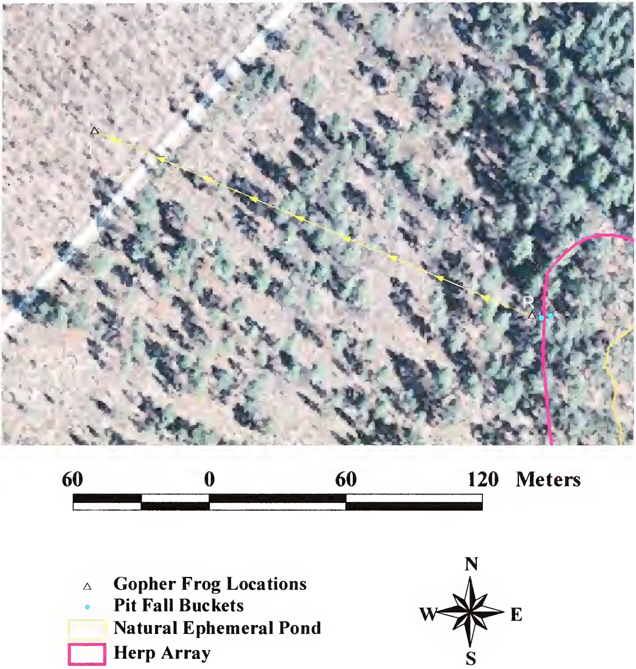

Figure 12. Radio-tracked Locations of Female Gopher Frog # 0.223

Appendix C. Gopher Frog Radio-tracking Data: Distances Moved Between Locations (March 2000 - March 2001)

GF ID #	Location	Distance From Previous Location (m)	Distance From Location Released (m)	Transmitter Found
0.141	R			
	1	19.04	19.04	
	2	618.2	598.9	Yes
0.126	R			
	1	40.54	40.54	No
0.042	R			
	1	19.63	19.63	
	2	256.3	270.53	No
0.084	R			
	1	224.51	224.51	
	2	44.5	246.79	Yes
0.184	R			
	1	188.25	188.25	No
0.223	R			
	1	212.4	212.4	Yes
0.244	R			
	1	141.53	141.53	
	2	4.24	138.99	No
0.205	R			
	1	29.38	29.38	
	2	105.5	135.81	
	3	52.4	84.12	
	4	56.4	29.38	
	5	4.2	31.45	
	6	64.1	94.93	
	7	23.3	119.03	
	8	28.4	135.81	
	9	91.5	197.58	
	10	48.6	150.69	
	11	128.5	62.1	Yes
0.159	R			
	1	85.79	85.79	
	2	48.3	134.69	
	3	38.1	157.31	
	4	38.1	134.69	No
0.105	R			
	1	96.3	96.3	
	2	20.2	112.88	No

Appendix C. Continued

GF ID #	Location	Distance From Previous Location (m)	Distance From Location Released (m)	Transmitter Found
0.063	R			
	1	53.42	53.42	
	2a	172	222.63	
	2b	172	222.63	Yes
0.022	R			
	1	110.94	110.94	
	2	36.2	127.22	
	3	47.5	121.16	
	4	2.3	122.66	
	5	2.3	121.16	
	6	2.3	122.66	
	7	48.4	127.22	
	8	47.2	121.16	
	9	144.2	26.56	
	10	22.5	41.34	
	11	22.2	19.42	Yes

GF ID # = Gopher frog identification number (transmitter frequency number).
R = Location Released (outside edge of herp array).
Location 11 of Gopher Frog # .205 is at outside edge of herparray.
Locations 9 and 10 of Gopher Frog # .022 are in artificial pond.
Location 11 of Gopher Frog # .022 is outside of artificial pond but inside the herp array.
Gopher Frog #.141 died after second implant surgery.
Locations 2a and 2b for gopher frog .063 are the same.
Confirmed Mortality: "Yes" = Transmitter was found. "No" = Transmitter signal lost and capture of individual was unsuccessful.

Appendix D. Habitat Use Data Per Individual Gopher Frog

GF ID #	Burrow #	Burrow Type	Burrow Status	Habitat Type	# of Weekly Observations Per Habitat Type	% Time Spent in Each Habitat Type
0.141	11.00	GT	INA	VII	3.00	25.00
	12.00	SM	AB	VI	9.00	75.00
0.126	13.00	GT	AB	VII	14.00	100.00
0.042	16.00	GT	AB	V	2.00	50.00
	17.00	SM	AB	V	2.00	50.00
0.084	14.00	SM	GT	VI	12.00	38.71
	15.00	GT	INA	VI	19.00	61.29
0.184	10.00	GT	INA	VI	8.00	100.00
0.223	9.00	GT	AB	III	14.00	100.00
0.244	18.00	SM	AB	V	13.00	37.14
	19.00	GT	AB	V	22.00	62.86
0.205	1.00	GT	AB	V	2.00	4.17
	2.00	SM	AB	V	7.00	14.58
	3.00	GT	ACT	V	1.00	2.08
	1.00	GT	AB	V	1.00	2.08
	4.00	GT	AB	V	2.00	4.17
	5.00	SM	AB	V	3.00	6.25
	6.00	GT	ACT	V	1.00	2.08
	2.00	SM	AB	V	5.00	10.42
	7.00	GT	INA	V	2.00	4.17
	8.00	SM	AB	V	24.00	50.00
	Outside edge of herp array (Dead)					
0.159	20.00	GT	INA	VI	4.00	26.67
	21.00	SM	AB	VI	7.00	46.67
	22.00	SM	AB	VI	1.00	6.66
	21.00	SM	AB	VI	3.00	20.00
0.105	23.00	GT	AB	VI	13.00	39.39
	24.00	GT	AB	VI	20.00	60.61
0.063	25.00	GT	AB	II	2.00	6.45
	26.00	GT	INA	V	21.00	67.74
	26.00	GT	ACT	V	8.00	25.81
0.022	27.00	SM	INA	II	8.00	19.51
	28.00	GT	AB	II	4.00	9.76
	29.00	GT	AB	II	6.00	14.63
	30.00	SM	INA	II	5.00	12.20
	29.00	GT	AB	II	1.00	2.44
	30.00	SM	INA	II	6.00	14.63
	28.00	GT	AB	II	1.00	2.44
	29.00	GT	AB	II	10.00	24.39
	Between herp array and pond edge (Dead)					

Appendix D. Continued

GF ID # = Gopher frog identification number
GT = Gopher Tortoise
SM = Small Mammal
ACT = Active
INA = Inactive
AB = Abandoned

Appendix E.

Table 1. Total Number of Gopher Frogs Known to Use Each Habitat Type; Total Number of Burrows Used, Weekly Observations and Percent Time Spent Per Habitat Type

Habitat Type	Total # of Gopher Frogs Known to Use Each Habitat Type	Total # of Burrows Used Per Habitat Type	% Time Spent in Each Habitat Type
I	0.00	0.00	0
II	2.00	5.00	15.03
III	1.00	1.00	4.9
IV	0.00	0.00	0
V	4.00	13.00	40.56
VI	5.00	9.00	33.57
VII	2.00	2.00	5.94

Appendix E – (Continued)

Table 2. Correlation Between Total Number of Gopher Frogs Known to Use Each Habitat Type; Total Number of Burrow's Used Per Habitat Type and Percent Time Spent in Each Habitat Type Using Pearson's Correlation Coefficient Method

		Total # of Gopher Frogs Known to Use Each Habitat Type	Total # of Burrows Used Per Habitat Type	% Time Spent In Each Habitat Type
Total # of Gopher Frogs Known to Use Each Habitat Type	Corr. Coeff. Sig. (2-tailed)	1 .	0.901 0.006	0.935 0.002
Total # of Burrows Used Per Habitat Type	Corr. Coeff. Sig. (2-tailed)	0.901 0.006	1 .	0.992 0
% Time Spent In Each Habitat Type	Corr. Coeff. Sig. (2-tailed)	0.935 0.002	0.992 0	1 .

Corr. Coeff. = Correlation Coefficient which ranges in value from -1 (a perfect negative relationship) to +1 (a perfect positiverelationship). A value of 0 indicates no linear relationship.

Sig. (2-tailed) = The significance level (or p-value) which is the probability of obtaining results as extreme as the one observed. If the significance level is very small (less than 0.05), then the correlation is significant and the two variables are linearly related. If the significance level is relatively large (for example, 0.50) then the correlation is not significant and the two variables are not linearly related.

Correlation is significant at the 0.01 level (2-tailed).

Appendix F – Habitat Types and Corresponding Timber and Burrow Measurements

Table 1. Habitat Type With Corresponding Pine-Hardwood Overstory and Midstory Basal Areas, and Number of Stems $\geq$ 25.4 cm DBH

Habitat Types	Basal Area Range (m^2/ha)	Mean Pine BA (m^2/ha)	Mean Hardwood BA (m^2/ha)	Total Mean BA (m^2/ha)	Mean # of Pine Stems ≥ 25.4cm DBH	Mean # of Hardwood Stems ≥ 25.4cm DBH	Mean # of All Stems ≥ 25.4cm DBH
I	2.0 - 2.4	0.66	1.64	2.30	0.00	0.00	0.00
II	3.0 - 3.4	2.58	0.57	3.15	0.63	0.00	0.32
III	3.5 - 3.9	0.26	3.27	3.53	0.00	0.00	0.00
IV	5.0 - 5.4	3.44	1.81	5.25	0.00	0.00	0.00
V	7.0 - 7.4	4.66	2.55	7.21	0.86	0.06	0.46
VI	9.5 - 9.9	9.12	0.67	9.79	2.36	0.18	1.27
VII	14.5 - 14.9	14.73	0.00	14.73	3.18	0.00	1.06

Appendix F – (Continued)

Table 2. Habitat Types With Corresponding Burrow Densities, Burrow Types Used and Number of Weekly Observations Per Burrow Type

Habitat Types	GT Burrow Density (# of Burrows/ha)	SM Burrow Density (# of Burrows/ha)	Total Burrow Density	Total # of Observations at GT Burrows	Total # of Observations at SM Burrows	Total # of Observations
I	2.80	42.06	44.86	0.00	0.00	0.00
II	5.26	231.34	236.60	24.00	19.00	43.00
III	6.88	105.15	112.03	14.00	0.00	14.00
IV	2.70	84.12	86.82	0.00	0.00	0.00
V	6.35	115.67	122.02	57.00	54.00	116.00
VI	3.68	31.55	35.23	67.00	23.00	96.00
VII	2.03	21.03	23.06	19.00	9.00	17.00

Appendix F - (Continued)

Table 3. Correlation Between Gopher Tortoise and Small Mammal Burrow Density, Number of Weekly Observations Per Burrow, Overstory and Midstory Basal Area, and Pine/Hardwood Stems $\geq$ 25.4 cm Using Spearman's Rank Correlation Method

		Mean Pine BA (m^2/ha)	Mean Hardwood BA (m^2/ha)	Mean Total BA (m^2/ha)	Mean # of Pine Stems ≥ 25.4 cm DBH	Mean # of Hardwood Stems ≥ 25.4 cm DBH	Mean Total # of Stems ≥ 25.4 cm DBH
GT Burrow Density (# of Burrows/ha)	Corr. Coeff.	-0.900	0.900	-0.700	-0.900	-0.112	-0.800
	Sig. (2-tailed)	0.037	0.037	0.188	0.037	0.858	0.104
SM Burrow Density (# of Burrows/ha)	Corr. Coeff.	-0.700	0.300	-0.900	-0.700	-0.112	-0.600
	Sig. (2-tailed)	0.188	0.624	0.037	0.188	0.858	0.285
Total Burrow Density (# of Burrows/ha)	Corr. Coeff.	-0.700	0.300	-0.900	-0.700	-0.112	-0.600
	Sig. (2-tailed)	0.188	0.624	0.037	0.188	0.858	0.285
Total # of Observations at GT Burrows	Corr. Coeff.	0.400	-0.100	0.200	0.400	0.894	0.700
	Sig. (2-tailed)	0.505	0.873	0.747	0.505	0.041	0.188
Total # of Observations at SM Burrows	Corr. Coeff.	0.300	0.000	0.100	0.300	0.783	0.500
	Sig. (2-tailed)	0.624	1.000	0.873	0.624	0.118	0.391
Total # of Observations	Corr. Coeff.	0.300	0.000	0.100	0.300	0.783	0.500
	Sig. (2-tailed)	0.624	1.000	0.873	0.624	0.118	0.391

Data from habitat I and IV were not included in the analysis because gopher frogs were not observed in either of them.

BA = Basal Area

Stem = Over and Mid-story Tree (i.e. pines and hardwoods)

DBH = Diameter at Breast Height

GT = Gopher Tortoise

SM = Small Mammal

Observations = Number of times a gopher frog was identified at a location on a weekly basis.

Corr. Coeff. = Correlation Coefficient which ranges in value from -1 (a perfect negative relationship) to +1 (a perfect positive relationship). A value of 0 indicates no linear relationship.

Appendix F - (Continued)

Table 3.

Sig. (2-tailed) = The significance level (or p-value) which is the probability of obtaining results as extreme as the one observed. If the significance level is very small (less than 0.05), then the correlation is significant and the two variables are linearly related. If the significance level is relatively large (for example, 0.50) then the correlation is not significant and the two variables are not linearly related.

Correlation is significant at the .05 level (2-tailed)

Correlation is significant at the .01 level (2-tailed)

Appendix G. Wilcoxon Paired-Sample Signed Ranks Test to Compare Gopher Frog Weights Prior to First Surgery to Weights Prior to Second Surgery

Two Tailed Test

H_O: Weights prior to the first surgery are not significantly different from weights prior to the second surgery.

H_A: Weights prior to the first surgery are significantly different from weights prior to the second surgery.

Gopher Frog j	Weight Prior to 1st Surgery (g) (X_{1j})	Weight Prior to 2nd Surgery (g) (X_{2j})	Difference ($d_j = X_{1j} - X_{2j}$)	Rank of $\lvert d_j \rvert$	Signed Rank of $\lvert d_j \rvert$
1	62	67	-5	2.5	-2.5
2	58	51	7	5	5
3	67	74	-7	5	-5
4	60	53	7	5	5
5	67	49	18	9	9
6	58	45	13	8	8
7	46	43	3	1	1
8	62	52	10	7	7
9	48	43	5	2.5	2.5

$\alpha = 0.05$

$n = 9$

T = Summed Ranks

T_+ = Summed Ranks with Plus Sign = 5 + 5 + 9 + 8 + 1 + 7 + 2.5 = 37.5

T_- = Summed Ranks with Minus Sign = 2.5 + 5 = 7.5

$T_{\alpha(2), n}$ = Critical Value of the Wilcoxon T Distribution = $T_{0.05(2), 9} = 5$

If T_+ or $T_- \leq$ Critical Value then H_O is rejected.

Since 37.5 and 7.5 are > 5, H_O is not rejected.