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September 1997

US Army Corps of Engineers
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Strategic Environmental Research and Development Program

Species Profile: Gopher Tortoise (*Gopherus polyphemus*) on Military Installations in the Southeastern United States

by Dawn S. Wilson, Henry R. Mushinsky, University of South Florida

Richard A. Fischer, WES

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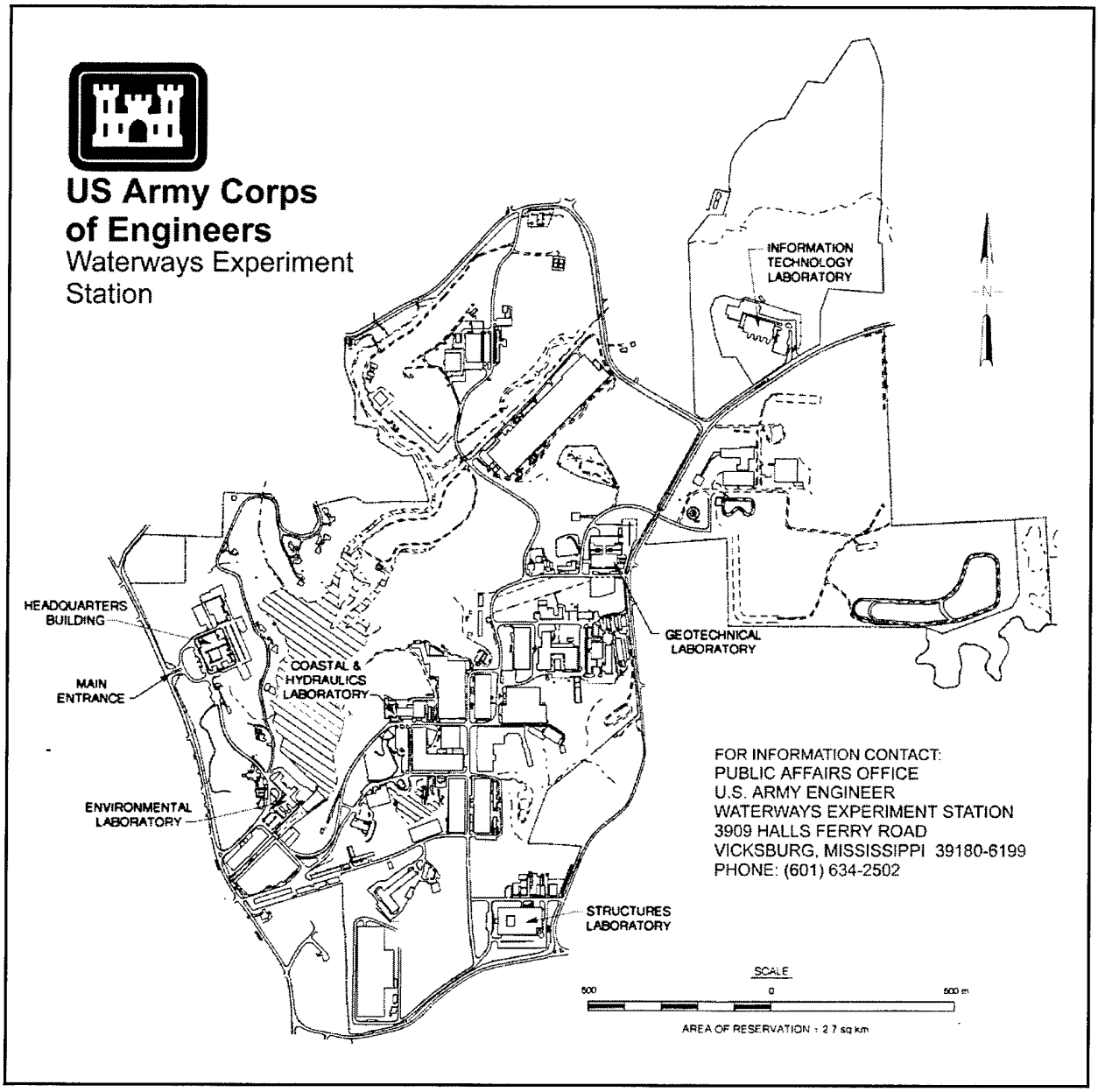

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Preface

The work described in this report was authorized by the Strategic Environmental Research and Development Program (SERDP), Washington, DC. The work was performed under the SERDP study entitled "Regional Guidelines for Managing Threatened and Endangered Species Habitats." Dr. John Harrison was Executive Director, SERDP.

This report was prepared by Ms. Dawn S. Wilson and Dr. Henry R. Mushinsky, Department of Biology, University of South Florida, Tampa; and Dr. Richard A. Fischer, Natural Resources Division (NRD), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. Portions of this report were taken or modified from The Nature Conservancy's Element Stewardship Abstract (ESA) titled "Species Stewardship Summary; *Gopherus polyphemus*" prepared by Ms. Wilson and Dr. Mushinsky. The ESA was prepared under contract with the U.S. Army Construction Engineering Research Laboratories (CERL), Natural Resources Division, Champaign, IL, for a document titled "Integrated Endangered Species Management Recommendations for Army Installations in the Southeastern United States: Assessment of Army-Wide Guidelines for the Red-Cockaded Woodpecker on Associated Endangered, Threatened, and Candidate Species."

Report review was provided by Dr. Joan Diemer-Berish, Florida Game and Fresh Water Fish Commission; Dr. Robert Herrington, Georgia Southwestern University; Mr. Dirk Stevenson, Environmental/Natural Resources Branch, Fort Stewart, Georgia; and Ms. Mary G. Harper, Illinois Natural History Survey, Champaign, IL. WES technical review was provided by Mr. Chester O. Martin, Ms. Dena Dickerson, and Mr. John Tingle, EL, WES. Mr. Martin, WES, and Ms. Ann-Marie Trame, Land Management Laboratory, CERL, were Primary Investigators for the work unit. Ms. Tiffany Cook, WES, provided valuable assistance in assembling this report.

This report was prepared under the general supervision of Dr. Michael F. Passmore, Chief, Stewardship Branch, NRD; Dr. Dave Tazik, Chief, NRD; and Dr. John Harrison, Director, EL.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES.

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Species Profile: Gopher Tortoise
(Gopherus polyphemus)

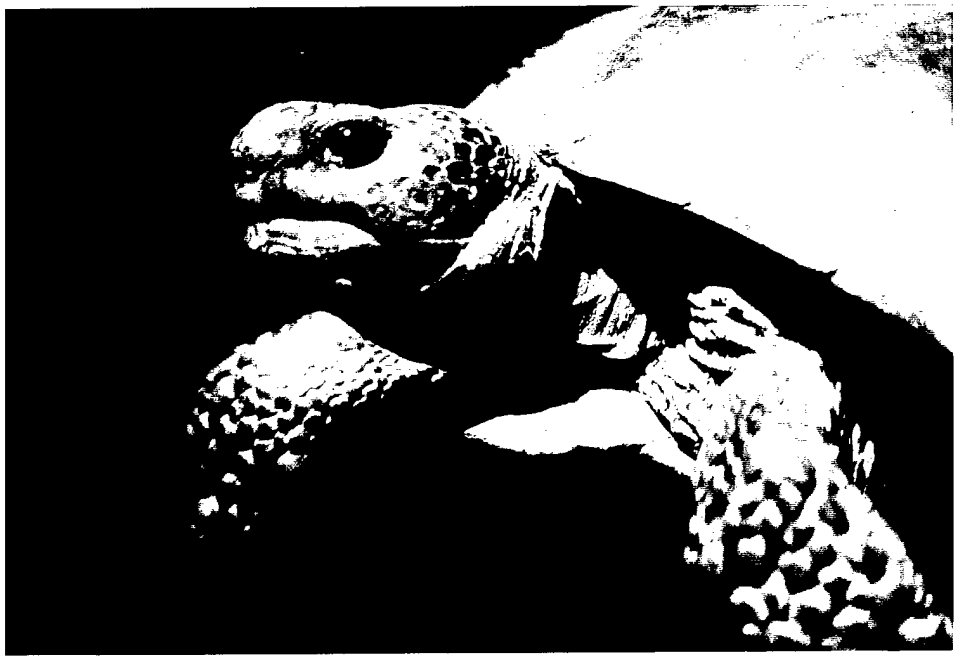

Photo by Joan E. Berish

Taxonomy

Class	Reptilia
Order	Testudines
Family	Testudinidae
Genus/species	*Gopherus polyphemus*
Other Common Names	Gopher; Hoover chicken

Description

The gopher tortoise is a terrestrial turtle with a dark-brown to grayish-black carapace (length 15 to 37 cm (5.9 to 14.6 in.)), elephantine hind legs, shovel-shaped forelimbs, and a gular projection below the head on the plastron (Ernst and Barbour 1972). Often in adults, the surface of the carapace is quite smooth, reflecting the abrasion it receives as an individual enters or exits burrows. The carapace is keelless and oblong, with the greatest width just anterior to the well-developed bridge (connecting the carapace to the plastron), and the greatest height in the sacral region. The carapace drops off abruptly to the rear of the highest region (Ernst and Barbour 1972). The neck projects through a tan to yellowish, hingeless plastron.

Female gopher tortoises become sexually mature at a carapace length of about 225 to 265 mm (8.86 to 10.43 in.), depending on latitude. Males are somewhat smaller at maturity and, on average, do not obtain as large a body size as females. The best indicator of the sex of an adult gopher tortoise is the depth of the plastral concavity (Mushinsky et al. 1994). Mature males have a shallow depression in the posterior, central portion of the plastron to facilitate mounting a female for copulation. Large females may have a shallow plastral concavity (2 to 4 mm (0.08 to 0.16 in.)) compared with the deeper concavity found on mature males (5 to 8 mm (0.20 to 0.32 in.)). Males often have larger glands under the chin than females (Ernst and Barbour 1989), but the size of these integumentary glands varies seasonally. Males often have greater gular projections than females; however, because both sexes use their projections during agonistic encounters, the gular projections are often broken and may not be an accurate diagnostic feature of the sex of an individual (Mushinsky et al. 1994). Based upon numerous anatomical measurements, McRae et al. (1981a) developed a discriminant function that accurately identified the sex of adult individuals. Using a stepwise multiple regression on numerous morphological measurements, Burke et al. (1994) developed a noninvasive technique for determining the sex of hatchling and juvenile gopher tortoises.

Most gopher tortoises have relatively well-defined "growth rings" on the scutes of the plastron. Use of growth rings to age individuals must be done with caution, as there is much variation in the number of "false" growth rings. Also, rings become less discernable on older tortoises (Mushinsky et al. 1994).

Hatchlings are yellowish-orange, have a soft shell, and are 4 to 5 cm (1.6 to 2.0 in.) long at hatching. The bright coloration of hatchlings darkens during the first year or two of life. The gular scutes of young tortoises do not project forward as in the adult tortoises, and the claws of young tortoises are long and sharp (Allen and Neill 1953). Hatchlings dig their own burrows, often just a few meters away from the nest from which they emerged. Hatchlings and juveniles, up to an age of 5 to 7 years, have relatively soft shells and are highly vulnerable to predation (Wilson 1991).

Similar Species

The gopher tortoise is the only tortoise species east of the Mississippi River. The only other terrestrial turtle within the geographic range of the gopher tortoise is the box turtle (*Terrapene carolina*). Box turtles are smaller than gopher tortoises, have a high domed carapace, and have a hinged plastron. Box turtles can close their shells completely so that neither the head nor any appendage is visible. Gopher tortoises cannot withdraw completely into their shells. A startled gopher tortoise will withdraw its limbs into the shell, but the limbs are visible when retracted.

Status

Legal designation

Federal. The western population of the gopher tortoise was listed as threatened by the U.S. Fish and Wildlife Service (USFWS) on 7 July 1987 (USFWS 1987). The first formal recovery plan for this population was developed by the USFWS (1990). The eastern population was a candidate species (C2) for listing as either threatened or endangered by the USFWS. However, the USFWS discontinued the designation of C2 species as candidates for listing (50 CFR 17; 28 February 1996). The gopher tortoise is considered to be a species of concern, but more biological research and field study are needed to resolve its conservation status.

State. The gopher tortoise is state listed as threatened in Georgia, a species of special concern in Florida, endangered in Mississippi and South Carolina, a protected nongame species in Alabama, and threatened in Louisiana.

Distribution and numbers

The gopher tortoise is one of four tortoise species native to North America, but is the only member of the genus *Gopherus* indigenous to the southeastern United States. It occurs primarily in xeric sandy upland habitats in the Southeast, ranging from southwestern South Carolina, through Georgia and Florida to southeastern Louisiana, with approximately 80 percent of remaining populations occurring in Georgia and Florida (Auffenberg and Franz 1982, Diemer 1989b) (Figure 1). It also occurs on islands off the Gulf coast of Florida as far south as Cape Sable (Logan 1981, Kushlan and Mazzotti 1984, Mushinsky and McCoy 1994). The listed population of the gopher tortoise occurs West of the Mobile and Tombigbee rivers in Alabama, Mississippi, and Louisiana. In 1984, the western population was relatively abundant in Mississippi and Alabama, but is "valiantly, though precariously hanging on" in Louisiana (Steve Shively, Personal Communication, 1996). For a detailed range map see Iverson (1992).

Eastern population

South Carolina—Populations occur only in portions of Jasper and Hampton counties in southwestern South Carolina. They are restricted to the ridges adjacent to the east bank of the Savannah River and west bank of the Coosawhatchee River.

Georgia—Populations occur in a series of disjunct populations south and east of the Fall Line, which separates the Piedmont and Coastal Plain physiographic regions in the southeastern United States.

Florida—Populations occur in portions of all 67 counties, but their current range in southern Florida is restricted due to unsuitable habitat and increased urbanization (Joan Diemer-Berish, Personal Communication, 1996).

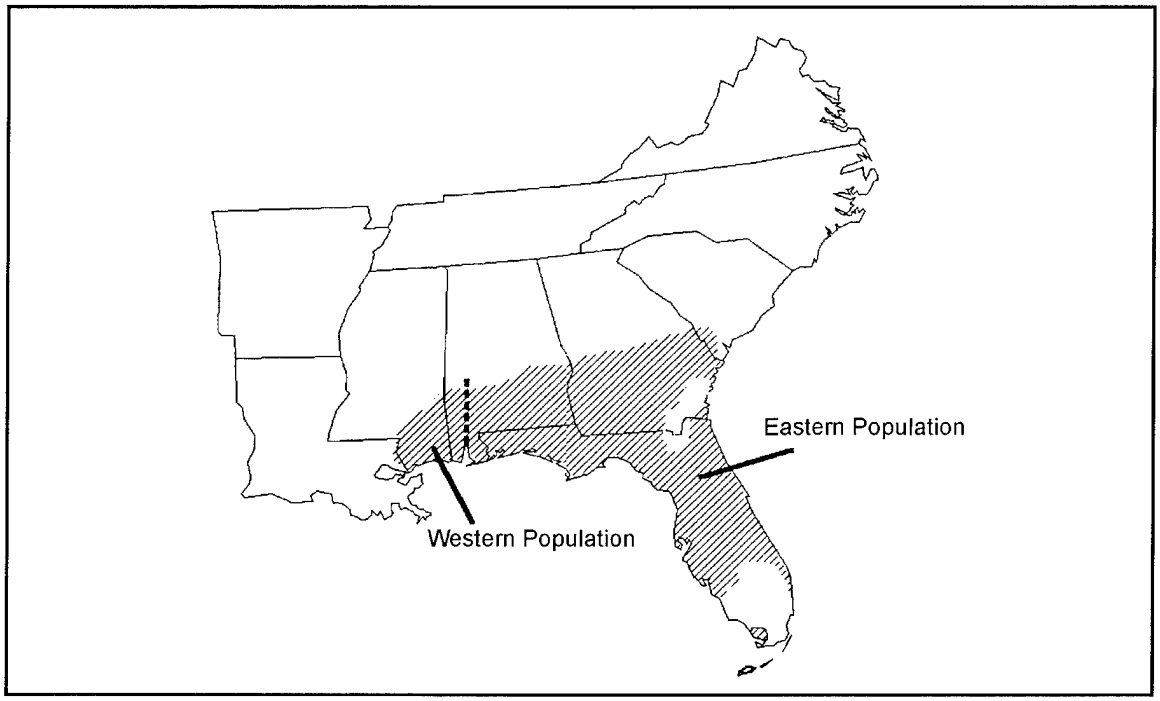

Figure 1. Approximate distribution of the gopher tortoise (from Auffenberg and Franz 1978, Ernst et al. 1994)

Alabama—Distribution is limited to the southern third of Alabama, south of the Fall Line, excluding those counties harboring the western population (see below).

Western population (USFWS 1990)

Alabama—Populations occur in Washington, northern Mobile, and southeastern Choctaw counties (40,770 ha).

Mississippi—Populations occur in a 14-county region in the southern portion of the State including the southeastern upland areas of the pinehills (102,984 ha).

Louisiana—Populations occur in upland pine ridges in St. Tammany, Washington, and Tangipahoa parishes (4,815 ha).

Military installations

See Table 1.

Significance of the Species

Gopher tortoises are the primary grazers in upland xeric habitats (Landers 1980) and probably are a primary seed disperser for native grasses (Auffenberg 1969). Gopher tortoises excavate deep burrows, which provide shelter from temperature extremes and

Table 1
Known Status of the Gopher Tortoise on Military Installations in the Southeastern United States

State	Installation	Federal Status	Status on Installation
GA	Fort Stewart	Species of concern (SOC)	Documented onsite; widespread and abundant with recent successful reproduction; at least 95 populations, 6 with ≥100 burrows. Populations are limited to sandhills, well-drained longleaf pine-palmetto-wiregrass flatwoods, and old fields on the western quarter of the installation and adjacent to the Canoochee River (The Nature Conservancy 1995b; Dirk Stevenson, Personal Communication, 1996).
	Fort Gordon	SOC	Documented onsite; abundant; suitable habitat was surveyed for the species from 1990 to 1992. Several young tortoises were observed, indicating recent active reproduction. Active and inactive burrows distributed in suitable habitat throughout the installation. Tortoise burrows occur within many training areas and artillery impact areas (Brooks and Laumeyer 1992).
	Georgia Army National Guard Training Center	SOC	Documented onsite.
	Marine Corps Logistics Base	SOC	Potential.
	Fort Benning	SOC	Documented onsite.
MS	Camp Shelby	Threatened	Documented onsite.
AL	Fort Rucker	SOC	Documented onsite; optimum habitats occur on Fort Rucker, especially in the eastern portion of the installation. Although some populations were found, most occurred as isolated individuals. Population size is low and probably <10 percent of carrying capacity. Major impacts include gassing burrows (Mount and Diamond 1992).
FL	Eglin Air Force Base (AFB)	SOC	Dobumented onsite.
	Tyndall AFB	SOC	Documend onsite (Stephen Shea, Personal Communication, 1996).
	Pensacola Naval Air Station (NAS)	SOC	Documented onsite (John Jensen, Personal Communication, 1997).
	Cape Canaveral Air Station	SOC	Documented onsite (Barbara Lenczewski, Personal Communication, 1997).
	Avon Park Air Force Range	SOC	Documented onsite.
	Naval Training Center, Orlando	SOC	Documented onsite (Barbara Lenczewski, Personal Communication, 1997).
	Mayport Naval Station	SOC	Documented onsite (Barbara Lenczewski, Personal Communication, 1997).
	NAS Cecil Field	SOC	Documented onsite (Hank Cochran, Personal Communication, 1996).
	MacDill AFB	SOC	Documented onsite (Shelley Urbinek, Personal Communication, 1996).

(Continued)

Table 1. (Concluded)			
State	Installation	Federal Status	Status on Installation
FL	NAS Jacksonville	SOC	Documented onsite at NAS Jacksonville; also occur on Outlying Field Whitehouse and Pinecastle Bombing Range, which both are noncontiguous areas with NAS Jacksonville (Sandra Maynard, Personal Communication, 1996).
	Orlando Naval Training Center	SOC	Documented onsite.
	Camp Blanding	SOC	Documented onsite.

refuge from predators. A large number of vertebrate species either use or are dependent on gopher tortoise burrows. Eastern indigo snakes *(Drymarchon corais couperi)* use tortoise burrows for year-round dens and egg-laying, and gopher frogs (*Rana capito* spp.) inhabit burrows (Auffenberg 1969, Auffenberg 1978, Diemer 1986), especially as diurnal retreats (Godley 1992). Landers and Speake (1980) found more than 40 vertebrate species using gopher tortoise burrows (Table 2). Jackson and Milstrey (1989) reported more than 60 vertebrates and 302 invertebrate species in gopher tortoise burrows. The enlarged area at the bottom of the burrow usually contains fecal matter and other organic debris, which serves as an important food source for many of these species (Milstrey 1986). Some gopher tortoise burrow associates have been shown to prefer either active or inactive burrows (Lips 1991). Eisenberg (1983) found that 74 percent of gopher frogs censused were found in active tortoise burrows. Witz et al. (1991) excavated 1,019 burrows and found that, of the vertebrate symbionts captured, only lizards were found significantly more often in active than in either inactive or abandoned burrows.

Life History and Ecology

Burrows

Gopher tortoises live in self-constructed burrows that are approximately 5 m (16.4 ft) in length and wide enough to allow easy rotation by tortoises at any point (Wilson et al. 1991). Most burrows are straight and unbranched and have an enlarged chamber at the end where the tortoise can sleep or turn around (Ernst et al. 1994). A major portion of the annual life cycle is spent in the burrow, which provides protection from fire, predators, and extreme temperatures. These burrows are downward sloped from the surface and taper off underground, and most have a single entrance. Tortoises typically require well-drained, sandy soils as burrow substrate (Landers 1980), although burrows are sometimes constructed in more clayey soils. Burrows have been found to be significantly shorter in clayey soils than sandy soils, which may be a result of respiratory limitations (Ultsch and Anderson 1986). The high humidity associated with the burrow may offer the tortoise protection from desiccation (Auffenberg and Weaver 1969, Means 1982). At the mouth of each burrow is a mound or terrace of subsoil excavated by the burrow resident. Kaczor and Hartnett (1990) found that these soil mounds undergo microsuccession

Table 2
Vertebrate Species Found in Gopher Tortoise Burrows in Georgia (Landers and Speake 1980)

Common Name	Scientific Name
Listed Species	
Indigo snake	*Drymarchon corais couperi*
Candidate and Former Candidate Species	
Florida pine snake	*Pituophis melanoleucus mugitus*
Gopher frog	Rana capito spp.
Other Species	
Eastern diamondback rattlesnake	*Crotalus adamanteus*
Eastern hognose snake	*Heterodon platirhinos*
Dusky pigmy rattlesnake	*Sistrurus miliarius barbouri*
Eastern coachwhip	*Masticophis flagellum flagellum*
Southern black racer	*Coluber constrictor priapus*
Box turtle	Terrapene carolina spp.
Six-lined racerunner	*Cnemidophorus sexlineatus sexlineatus*
Broad-head skink	*Eumeces laticeps*
Eastern newt	*Notophthalmus viridescens*
Fowler's toad	*Bufo woodhousii fowleri*
American toad	Bufo americanus americanus
Southern toad	Bufo terrestris
Eastern spadefoot toad	Scaphiopus holbrooki holbrooki
Eastern narrow-mouthed toad	*Gastrophryne carolinensis*
Old-field mouse	Peromyscus polionotus
Cotton mouse	*Peromyscus gossypinus*
Cotton rat	Sigmodon hispidus
Cottontail rabbit	Sylvilagus floridanus
Red fox	Vulpes vulpes
Gray fox	Urocyon cinereoargenteus
Raccoon	*Procyon lotor*
Opossum	*Didelphis virginianus*
Striped skunk	Mephitis mephitis
Bobwhite quail	*Colinus virginianus*
Carolina wren	*Thryothorus ludovicianus*
Burrowing owl	*Speotyto cunicularia*

and contribute toward increased plant species diversity in the surrounding habitat. Gopher tortoise burrows can be classified as active, inactive, or abandoned by the physical appearance of the entrance (Auffenberg and Franz 1982, Cox et al. 1987) (Table 3).

Table 3
Gopher Tortoise Burrow Activity Categories (Brooks and Laumeyer 1992 (from Lohoefener 1988))

Burrow Status	Description
Active	The burrow's mouth retains its classic half-arc shape; burrow may not be obscured by cobwebs although some cobwebbing may be present; burrow not obscured with leaves or other detritus; usually a few feces are around the mound; foraging paths are usually present and well-defined; some loose soil is usually present on the tunnel's floor.
Inactive	The burrow's mouth retains its classic half-arc shape; burrow usually with extensive cobwebs and leaves or other detritus; feces, if present, are old and weathered; foraging paths may not be present or are not well-defined; soil on the mound and on the tunnel's floor is hard-packed.
Abandoned	The burrow's mouth is eroded and usually no longer retains the half-arc shape; no gopher tortoise sign present; often the burrow will have been modified by an armadillo (*Dasypus novemcinctus*) or other animal.

In northern Florida, Diemer (1992c) found that, on average, adult male tortoises use 5.5 burrows, and adult female tortoises use 2.7 burrows per activity season (April-December). In Georgia, male and female tortoises were reported to use 7 and 4 burrows, respectively (McRae et al. 1981b). Mean annual burrow use by juvenile tortoises ranged from 1.1 by 0- to 1-year olds, 2.2 by 2-year olds, 1.7 by 4- to 5-year olds in a southern Georgia population (McRae et al. 1981b), and 4.4 burrows (1- to 4-year olds) in a central Florida population (Wilson et al. 1994). Suggested reasons for differences in burrow use among populations were differences in ground cover, soil composition, temperature extremes at different latitudes, and number of disturbances to burrows. Although juvenile tortoises use several burrows, they spend most of their time in a primary burrow. Annual use of the primary burrow for juvenile tortoises in a central Florida population was 75 percent of the use of all burrows (Wilson et al. 1994). The data for estimated use of the primary burrow for adult gopher tortoises are not available. Gopher tortoises will use shallow depressions, possibly as resting sites when traveling far from their burrows (Fucigna and Nickerson 1989, Godley 1989, Stout et al. 1989, Diemer 1992c). They also occasionally burrow under windrows, possibly for protection from cattle and machinery (Diemer 1992c).

In northern Florida, Diemer (1992b) found that the number of burrows showing signs of recent activity increased in April, peaked in July, and remained high through October. The burrow surveys showed a continuous cycle of burrow creation and abandonment. The ratio of captured tortoises to burrows (active and inactive) varied among sites and years.

Reproduction and development

Body size, rather than age, seems to determine sexual maturity in gopher tortoises. Female gopher tortoises become sexually mature between 10 and 21 years at a carapace length of 22 to 26 cm (8.7 to 10.2 in.) (Ernst et al. 1994). In southern Georgia, it may take from 19 to 21 years for females to become sexually mature (Landers et al. 1982), while in central Florida, females may mature in 9 to 11 years (Mushinsky et al. 1994). In part, this variation reflects the long activity season available to tortoises in central Florida. In addition to geographic location, however, local conditions also influence the number of years required to achieve sexual maturity. For example, one study of gopher tortoises in central Florida (Godley 1989) found that females attain sexual maturity in 14 to 16 years, while the Mushinsky et al. (1994) study from the same county found that females attain sexual maturity in 9 to 11 years. The study area occupied by the faster maturing females was a frequently burned sandhill habitat, whereas the other study area was a mosaic of habitats including pine (*Pinus* spp.) flatwoods and mixed mesic forests. Males likely mature at a smaller size than females. In north Florida, Diemer and Moore (1994) reported males that were apparently mature at a carapace length of about 18 cm.

Gopher tortoises reportedly mate during fall and spring, but peak mating occurs during May and June (Landers et al. 1980, Iverson 1980). Females typically ovulate during late spring, and most complete ovulation by late May (Iverson 1980). There is some evidence that dominant males breed with several females (Douglass 1990). When seeking a female, a male will move to the mouth of a burrow occupied by a female and display a head-bobbing behavior (Auffenberg 1966, Wright 1982). If the female exits her burrow, the courting male will walk in a circle around the female, periodically stopping and performing the head-bobbing behavior. When the female approaches the courting male, he bobs his head violently, and bites her on the forelegs, head, anterior edge of the carapace, and gular projection. The female then backs in a semicircle, stops, and extends her hindlimbs. Thereafter, she rotates her body about 180 degrees, so that her posterior end is near the male's head. The courting male will attempt to mount the female, and if unsuccessful, he will repeat the courting behavior (Auffenberg 1966, Ernst and Barbour 1972).

Nesting can occur from late April to mid-July, but primarily occurs from May through mid-June (Iverson 1980, Landers et al. 1980, Wright 1982, Butler and Hull 1996). In southern Georgia, nests were placed in the spoil mound or burrow apron immediately outside the female's burrow (Landers et al. 1980, Butler and Hull 1996). However, in northern Florida, nests were typically located in any open sunny area near or some distance away from the burrow of the female (Smith 1995); Butler and Hull (1996) found 4 of 25 nests (16 percent) in a grassy field not associated with a burrow. In Florida, mean nest depth to the top of the uppermost egg was 12.6 cm, and mean distance from the burrow mouth to nest was 40.8 cm (Butler and Hull 1996). Female gopher tortoises lay a single annual clutch of 1 to 25 (typical range is 4 to 9) white, spherical eggs (Brode 1959, Wright 1982, Iverson 1980, Burke 1987). Clutch size of gopher tortoises has been shown to increase with increasing carapace length of females in northern Florida (Diemer and Moore 1994) and with plastron length in southern Georgia (Landers et al. 1980). A large female from central Florida produced an unusually large clutch of 25 eggs (Godley

1989). Incubation ranges from 80 to 110 days depending on latitude (Iverson 1980, Landers et al. 1980, Wright 1982). In Florida, hatchlings emerged from nests from late August through early October (Butler and Hull 1996); there is no parental care upon hatching.

Landers et al. (1980) suggested that, in south Georgia, only 23 percent of eggs survived the incubation period; most eggs were consumed by small mammals such as raccoons (*Procyon lotor*) and striped skunks (*Mephitis mephitis*). Robert Herrington (Personal Communication, 1996) suggested that only 1 in 10 nests successfully hatch.

In Georgia, Landers et al. (1982) reported pronounced growth of tortoises through the age of 11 years, after which growth rates gradually decrease. In central Florida, Mushinsky et al. (1994) reported an average increase of 18.9 mm (0.74 in.)/year for ages 1 to 11, after which time growth slows to approximately 3 percent/year until age 20.

Home range and movements

Gopher tortoises spend a limited amount of time outside of their burrows, and they are most active during spring and summer. During winter, tortoises have been observed basking at the mouths of their burrows on warm days throughout their range (Douglass and Layne 1978, McRae et al. 1981b, Wilson et al. 1994). The activities of gopher tortoises away from their burrows are limited in winter and increase as seasonal temperatures increase.

The gopher tortoise has a well-defined home range (Ernst et al. 1994). As the tortoise ages and becomes larger, the size of its home range increases. Estimated sizes of activity ranges for adult female gopher tortoises range from 0.08 ha (McRae et al. 1981b) to 0.56 ha (0.20 to 1.38 acres) (Doonan 1986) and adult males from 0.45 ha (1.11 acres) (McRae et al. 1981b) to 1.27 ha (3.14 acres) (Diemer 1992c). The activity range for juveniles (1 to 4 years), ranges from 0.01 to 0.36 ha in a central Florida population (Wilson et al. 1994) and <0.01 to 0.25 ha in a north Florida population (Diemer 1992c). Similar to adults, Wilson et al. (1994) found that home ranges of juveniles were larger in summer than in the other seasons. The size of the activity range of the gopher tortoise has been shown to decrease with an increase in the amount of herbaceous ground cover (i.e., food resources) (Auffenberg and Iverson 1979, Mushinsky and Gibson 1991).

In south Georgia, daily activity has been reported as unimodal in the spring and bimodal in summer (McRae et al. 1981b). During July and August, there are two peak foraging activity periods; midmorning (1000 to 1200 hr) and midafternoon (1600 to 1800 hr); activity was greatly reduced during the hottest part of the day (1300 to 1500 hr). In south Florida, daily activity cycle is unimodal, and activity occurs between 1000 and 1400 hr (Douglas and Layne 1978). Douglass and Layne (1978) and Wilson et al. (1994) found that juvenile tortoises were more active in the midafternoon and did not display a bimodal activity pattern in summer. Activity patterns of juvenile tortoises may be influenced by the risk of predation and thermoregulatory behavior (see Wilson et al. 1994 and Wilson 1991). No evidence of nocturnal activity has been reported for the gopher tortoise.

Gopher tortoises typically move only short distances from and between burrows (Diemer 1992c, Wilson et al. 1994). Excluding moves between burrows, movements away from the burrow have been considered a tortoise's feeding radius. McRae et al. (1981b) reported a mean feeding radius of 7.8 ± 4.4 m (25.6 ± 14.4 ft) for juvenile tortoises and 13.0 ± 8.6 m (42.7 ± 28.2 ft) for adult tortoises in a south Georgia population. In central Florida, Wilson et al. (1994) reported a mean feeding radius of 7.9 ± 8.6 m (25.9 ± 28.2 ft) for juveniles. Tortoises have also been reported to make long-distance movements. Diemer (1992c) found that the longest movement of a radio-tagged animal was 0.74 km (0.46 miles) by an emigrating subadult. Juveniles may make long-distance movements following disturbance to the resident burrow (Diemer 1992c, Wilson et al. 1994).

Population biology

A comprehensive study of about 50 populations of gopher tortoises in Florida (McCoy and Mushinsky 1988) suggested several trends. Gopher tortoise populations residing on sites that had experienced severe area reduction (greater than 25-percent reduction over the past 20 years), or sites with greater than 50-percent tree canopy or relatively small sites (<2 ha), tended to have truncated demographic profiles (i.e., fewer older individuals). A truncated profile suggests little recruitment of individuals into the population and abandonment of the site by larger, mature individuals. In contrast, tortoise populations on sites with no or limited area reduction, or sites with less than 50-percent tree canopy, or relatively large sites (>2 ha), tended to have a high proportion of large, mature individuals and evidence of recruitment of young into the population (McCoy and Mushinsky 1988).

Comparisons of tortoise populations on true islands with populations on the mainland suggested that tortoises do respond to relatively small, isolated habitats (Mushinsky and McCoy 1994). Both island and mainland tortoise populations showed a positive relationship between the number of active and inactive burrows and the area of habitat. Density of burrows, however, decreased as area increased on the mainland, but density of burrows was not related to area on the islands. Also, on the mainland, the ratio of inactive to active burrows (a measure of the tendency of individuals to construct new burrows) increased with area of habitat, and burrow density increased with increasing herbaceous vegetation; but neither of these relations could be demonstrated on islands. Collectively, these findings suggest that tortoises have a greater selection of habitats on the mainland than on islands. Tortoises on islands are confined and may be forced to live in less than ideal conditions. The implications of these findings are profound for tortoises living in small, fragmented "habitat islands" on the mainland. In time, perhaps a few decades, as the quality of their habitat island is degraded, mature adults may be forced to abandon a site in search of better habitat quality. Such individuals, which may be forced to abandon isolated patches of habitat in areas surrounded by human dwellings, seem doomed. Prior to Mushinsky and McCoy's (1994) study, observing large numbers of active and inactive gopher tortoise burrows in a confined area likely would have been viewed as an indicator of a "healthy" population; however, their findings suggested just the opposite. Rather than a signal of a healthy population, large numbers of active and inactive gopher tortoise burrows, relative to the actual number of tortoises, may signal a stressed population (see also Stewart et al. (1993)).

Food habits and foraging

Gopher tortoises are herbivorous and feed primarily on grasses and other herbaceous plants (Carr 1952, Garner and Landers 1981). In Florida and Georgia, gopher tortoises forage mainly on wiregrass *(Aristida stricta)*. In the western parts of their range, they often consume bluestem *(Andropogon* spp.), crabgrass *(Digitaria sanguinalis)*, and panic grasses *(Panicum* spp.*)* (Wahlenberg 1946, Garner and Landers 1981). Garner and Landers (1981) found that fleshy fruits were consumed when available, including blackberry *(Rubus cunefolius)*, sloeplum *(Prunus umbellata)*, maypop *(Passiflora incarnata)*, and hawthorne *(Crataegus* spp.*)*. Animal scat and carrion may be eaten when available (Robert Herrington, Personal Communication, 1996). Most tortoises feed near their burrows, suggesting that they do not frequently explore great distances during foraging (Landers et al. 1982). The gopher tortoise will drink water when available, often drinking rainwater that collects at the entrance of the burrow (Ashton and Ashton 1991).

Macdonald and Mushinsky (1988) identified 26 families of plants from 68 genera in scat analyses and foraging observations of gopher tortoises. The most common families of plants ingested were the Poaceae, Asteraceae, Fabaceae, Pinaceae, and Fagaceae. The most common genus of plants ingested was *Aristida* (see also Wright 1982). Insects were found in 75 percent of scats suggesting intentional ingestion. Young tortoises tend to ingest fewer plants of the family Poaceae and plants with external defense mechanisms and more forbs such as legumes than adults (Garner and Landers 1981, Macdonald and Mushinsky 1988). Macdonald and Mushinsky (1988) concluded that gopher tortoises tend to fall somewhere between a generalist and a specialist forager and prefer some plants over others with respect to their availability in the habitat. Rocks may be intentionally ingested as a source of minerals. During a study on the reproduction of adult female gopher tortoises in central Florida, radiography revealed that a large proportion of the females contained rocks in their digestive tracts (Mushinsky and Wilson, unpublished data). Digestive efficiencies of the gopher tortoise have been studied by Bjorndal (1987).

Predation

Adult tortoises have few predators because of their size and body structure (Wilson 1991), although predation on gopher tortoise eggs and young is high. In Georgia, an average female is estimated to produce a successful clutch of eggs (eggs are not destroyed prior to hatching) only once a decade (Landers et al. 1980), because about 90 percent of nests are destroyed annually. Common predators of eggs are armadillos, raccoons *(Procyon lotor)*, gray fox *(Urocyon cinereoargenteus)*, striped skunks, opossums *(Didelphis virginianus)*, snakes *(Crotalus, Drymarchon, Masticophis)*, and fire ants *(Conomyrma* spp., *Solenopsis* spp.) (Ernst and Barbour 1972, Douglass and Winegarner 1977, Landers et al. 1980, Diemer 1986, Martin 1989, Smith 1995).

The soft carapace of hatchlings (individuals in their first few years of life) makes them excellent prey (Landers et al. 1982). Results from two studies in central and northern Florida that combined mortality of eggs and hatchlings suggested an annual mortality rate >92 percent (Alford 1980, Witz et al. 1992). Estimated rates of survivorship of juvenile gopher tortoises (age 1 to 4 years) have been reported from one location

in central Florida (Wilson 1991). Wilson (1991) found that predation of juvenile tortoises was higher in October-November and April-May than any other 2-month intervals of the year. Juvenile tortoises are known to bask at the mouths of their burrows more often in spring and fall than during summer or winter months (Wilson et al. 1994). Juvenile tortoises positioned at the mouth of the burrow to thermoregulate during the cool months of the year may be quite vulnerable to avian and mammalian predators (Wilson 1991, see also Fitzpatrick and Woolfenden 1978).

Other

Wilson (1991) identified five age classes for gopher tortoises: eggs, hatchlings (up to 1 year), juveniles (1 to 4 years), subadults (5 to 15 years), and adults (16+ years). Physical features of juveniles are relatively the same as hatchlings although scute centers become distinctively yellow and laminal spurs become more prominent. In the subadult stage, the carapace toughens and coloration fades to a brown or tan. Hardening of the shell provides subadults a better chance of surviving predator attack. The adult carapace is completely hardened and dark.

Habitat Requirements

The gopher tortoise occupies a wide range of open, upland habitats with a well-drained, deep sandy substrate (required for burrowing), primarily longleaf pine (*P. palustris*)-xerophytic oak (*Quercus* spp.) woodlands (sandhills) but also xeric hammock, sand pine (*P. clausa*) and oak scrub, pine flatwoods, coastal grasslands, dry prairie, and a variety of ruderal and successional habitat types (Landers and Speake 1980, Auffenberg and Franz 1982, Kushlan and Mazzotti 1984, Diemer 1986, Diemer 1992a). These habitats are suitable for construction of its extensive burrows, contain ample herbaceous vegetation for food, and provide sunny areas for nesting and thermoregulation (Hallinan 1923, Landers 1980, Landers et al. 1980, Diemer 1989b).

The gopher tortoise usually abandons densely canopied areas and can also be found in disturbed habitats such as roadsides, fencerows, old fields, and the edges of overgrown (unburned) uplands (Diemer 1989b, Stewart et al. 1993, Breininger et al. 1994). Upland habitats with extensive canopy cover can decrease sunlight penetration and hamper the ability of tortoises to attain minimum thermal requirements for normal daily activities. Low sunlight also can decrease herbaceous vegetation essential for tortoise growth, development, and reproduction (Mushinsky and McCoy 1994). Densities of gopher tortoises are known to be relatively high in some sandhill and disturbed communities; however, high densities may not be indicative of a healthy population (Mushinsky and McCoy 1994). Mushinsky and McCoy (1994) report that high densities of some tortoise populations may be the result of tortoises confined to a true or "habitat" island. Tortoises in this situation are unable to move freely to new locations as the quality of the habitat degenerates. More research is needed on the demography of tortoises in confined areas.

Habitat Assessment Techniques

Little or no information was available in the published literature to adequately describe techniques for gopher tortoise habitat assessment.

Inventory and Monitoring—Census Methods

Direct

Techniques are available for detecting gopher tortoises in burrows, such as video cameras, listening devices, and bucket traps. However, determining population size by these methods can be expensive, time-consuming, and difficult because of the tortoise's reclusive nature.

Indirect

Because gopher tortoises dig burrows, estimates of the number of tortoises in a population commonly have been based on surveys of tortoise burrows (Carr 1952, Alford 1980, Cox et al. 1987). However, counts of tortoise burrows have no known relation to population size or density because the number of burrows used by gopher tortoises is not well known and can vary with habitat. Tortoises will use ≥1 burrow at a time (McRae et al. 1981b, Auffenberg and Franz 1982), thus burrows are presumed to outnumber tortoises (Humphrey et al. 1985).

Because not all burrows in a population are occupied, this indirect method requires the calculation of a correction factor that relates number of tortoises to the number of burrows. Based on the results of a long-term study (Auffenberg and Franz 1982), a "standard correction factor" of 0.614 was adopted by the Florida Game and Fresh Water Fish Commission. Combined counts of active and inactive burrows are multiplied by the correction factor to determine the number of tortoises present relative to the number of burrows present in a population. Several authors have suggested that accurate correction factors must be site specific (Burke 1989, Godley 1989, Stout et al. 1989, Breininger et al. 1991, Diemer 1992b). Clearly, one must establish a tortoise/burrow relationship for each site before an accurate interpretation of the data derived from burrow counts at a specific site can be made. A study of 26 populations of gopher tortoises showed that the "standard correction factor" overestimated the number of tortoises present in 22 of the 26 populations. With proper caution, an accurate estimate of tortoises present in a population can be made by an accurate assessment of active burrows in a population (see McCoy and Mushinsky (1992a)).

Repeated surveys, perhaps spaced over a period of 5 to 10 years, could provide information about population trends. Demographic profiles can be constructed by evaluating the size distributions of burrows and the number of active, inactive, and abandoned burrows in a population. One can use these profiles to evaluate the relative demographic "health" of populations (Mushinsky and McCoy 1994). A healthy population should

have some very large (old) tortoises and show signs of recent recruitment (see Cox et al. (1987)).

Impacts and Cause of Decline

The gopher tortoise is a long-lived species that has delayed sexual maturity and a low-reproductive potential. These demographic factors make gopher tortoise populations extremely vulnerable to reduction in population numbers. Historically, gopher tortoises were considered common in extensive tracts of southeastern longleaf pine communities maintained by frequent, lightning-caused fires. However, this species is now threatened with extinction in many areas and is in serious decline in others due to a variety of impacts. Habitat destruction and degradation (e.g., fire suppression), as well as habitat fragmentation, have contributed to the decline of this species. Poor habitat management also is a serious threat to the persistence of gopher tortoise populations. As the habitat becomes increasingly overgrown, large sexually mature adults will leave the population in search of better forage, resulting in a decrease in the recruitment of young into the population. In combination, the effects of area reduction and habitat degradation likely increase the probability of emigration in a synergistic fashion. Overharvesting by humans also historically limits population numbers; however, because of prohibition or regulation of harvest throughout most of its range, collecting of the gopher tortoise for food has declined.

Although a few human activities benefit the tortoise (e.g., controlled burning), most are detrimental. Agricultural clearing (e.g., conversion of upland habitats to citrus groves and agriculture fields), urban expansion, mining (e.g., phosphate mining in central Florida), and certain forestry practices are the most harmful effects. Although agricultural clearing is declining, past clearing has greatly reduced the distribution of gopher tortoises. Critical forest habitats in the tortoise's range often are harvested. Recently, selective lumber cutting has been replaced by pulpwood production. This practice produces dense, deeply shaded stands that are of little use to the gopher tortoise. When this occurs, either the tortoises die from lack of food or they relocate. After harvesting pine stands, slash material often is burned, and rows of slash pine (*P. elliottii*) are sometimes replanted. For a short period of time (i.e., 10 to 15 years), the area provides open and grassy areas that are suitable tortoise habitat. After this period, however, tree growth creates a thick canopy that is unsuitable habitat (Auffenberg and Franz 1982). Other impacts to gopher tortoise populations include predation on eggs and young by raccoons and other predators and predation by humans. Any development that fragments a population and/or creates a barrier to the natural movement of gopher tortoises will have an influence on that population. Rattlesnake roundups in some parts of its range (e.g., Opp, AL; and Whigham, GA) may have reduced populations in some areas. Gasoline often is introduced into the burrow to expel rattle, which can kill tortoises and many other burrow commensals (Speake and Mount 1973, Williams 1990, Wahlquist 1991). Gopher tortoise flesh is considered by some to be a delicacy and an aid for relieving high blood pressure and impotence. Tortoises were once a reliable source of food during the Great Depression. Although illegal throughout its range, turtle harvesting for food continues to a small degree (Puckett and Franz 1996).

Florida

In Florida, major causes of the species' decline include increased urbanization, phosphate mining, unmanaged habitats, and citrus production. This widespread development and destruction of Florida's upland habitats result in fragmentation of large tortoise populations and force individuals into unsuitable habitats and onto highways (Diemer 1989b). In the Florida panhandle, human predation on tortoises has drastically reduced populations (Auffenberg and Franz 1982, Taylor 1982, Diemer 1986). Another problem facing the gopher tortoise in the Florida panhandle is the planting of sand pine plantations. The dense canopy of closely packed pine trees shades the understory preventing the growth of grasses and herbaceous plants that provide food for gopher tortoises (Landers and Buckner 1981).

Georgia

In Georgia, large populations of tortoises have been fragmented by extensive agricultural and urban development, the construction of dams, and sand extraction (Landers and Garner 1981, Diemer 1989b). Human predation also is a threat to many tortoise populations throughout the Georgia Coastal Plain.

Mississippi

In Mississippi, habitat loss to crops and pasturage is the primary reason for the tortoise's decline.

Alabama

Alabama populations are reported to be recovering from past exploitation, but these populations are in danger of habitat degradation as a result of fire exclusion (Lohoefener and Lohmeier 1984).

South Carolina

In South Carolina, a few tortoise populations are located in the southern most parts of the State; however, these populations are threatened by human predation and slash pine monocultures (Auffenberg and Franz 1982).

Louisiana

The western population of the gopher tortoise is listed as threatened throughout its historic range as a direct result of human impact. In Louisiana, most of the tortoise habitat has been converted into pine plantations, and this conversion has pushed the tortoise into near extinction in this peripheral part of its range (Auffenberg and Franz 1982, Lohoefener and Lohmeier 1984). When the canopy becomes dense, less food is available and the tortoises disappear. These practices are foreseen to eliminate the tortoise from its Louisiana habitat.

Military training (adapted from Trame and Harper, in preparation)

Mechanized training. Mechanized military training can alter natural plant communities through impacts to soils and subsequently cause soil erosion. Intense use of tactical land vehicles (both tracked and wheeled) can cause extensive soil disturbance, which may destroy nests and burrows; individual tortoises may also be killed.

Bivouacs. Military bivouacs, which involve a combination of vehicle and nonmechanized trampling, represent a serious source of soil compaction and related impacts. Even frequently used bivouac sites may retain ground cover and pine regeneration if the soils are resistant to compaction. However, sustained high levels of trampling can ultimately eliminate vegetation in gopher tortoise habitat.

Fire. Military training can impact native communities and associated species by fragmenting the fuel sources needed to carry fire over large areas. Native ground cover, especially grasses, are essential fuel sources that allow large areas to burn. Bunchgrasses are often eliminated in bivouac sites, assembly areas, and tank maneuver areas through direct destruction or soil compaction. Areas that do not burn undergo a change in species composition and become increasingly shaded through time, resulting in the loss of the natural community.

The most potentially beneficial effect of military training activities is the reintroduction of fire resulting from activities such as live arms firing and use of incendiary devices. The frequency of ignition on military installations, especially in high hazard impact areas, often produces a fire regime over large areas at a frequency that resembles presettlement natural fire return intervals. This encourages a mosaic burn pattern and enhances conditions for the fire-adapted species (Gulf Engineers and Consultants, Inc., and Geo-Marine 1994; LeBlond et al. 1994).

Management and Protection

Effective management practices for gopher tortoise habitat include selective tree harvesting, natural regeneration, thinning dense oaks, and frequent burning. Habitat management that reduces the canopy and promotes a lush herbaceous ground cover (burning or stand thinning) is necessary to maintain a healthy population of tortoises. Prescribed burning is the preferred method for managing gopher tortoise habitats (Landers 1980, Mushinsky and Gibson 1991). The goal should be to produce a mosaic of vegetation density by altering the frequency and timing of controlled burns (Diemer-Berish 1994). A multiaged forest is desirable, ranging from treeless areas with high diversity and abundance of grasses and herbaceous plants, to areas with tree canopies that cover about 30 to 50 percent of the area. Recommendations for specific management procedures for gopher tortoises have been made by Landers and Speake (1980) for Georgia, Wright (1982) for South Carolina, Lohoefener and Lohmeier (1984) for Louisiana, Mississippi, and Alabama, and Auffenberg and Franz (1982) and Diemer (1986) for Florida. The details of any habitat management

program aimed at maintaining or increasing the number of gopher tortoises present in an area must be site specific.

Fire

Regular prescribed burning is highly desirable for the maintenance and improvement of gopher tortoise habitat because it reduces the shrub and midstory woody vegetation and promotes a well-established herbaceous layer. Adjacent pine flatwoods also should be subjected to summer burns on a 1- to 3-year cycle to encourage the production of the plants used as forage by gopher tortoises. Sand pine scrub habitat burns less frequently, perhaps every 15 to 30 years. A highly overgrown site may be first burned during winter months to reduce the risk of a hot fire. Thereafter, a cycle of summer burns should be implemented.

Activity ranges for this species vary between populations depending on the quality of the habitat (Diemer 1992c, Mushinsky and McCoy 1994). Dense unmanaged (e.g., unburned) areas often force tortoises to relocate to roadsides and fire lines where they may experience higher mortality.

Season of burn. Growing season burns should be preferred over winter burns since the former favors the control of encroaching hardwoods and maintenance of the wiregrass-dominated herbaceous layer. Summer burning mimics the natural fire cycle, promotes flowering of annual herbaceous plants, and facilitates the production of seeds by many of the grasses. Sandhill habitat responds well to summer burns on a 2- to 5-year periodicity. Managers may want to consider burning gopher tortoise habitat prior to August, when eggs begin to hatch.

Fire breaks. Natural fire breaks (topographic features, wetland boundaries) should be favored over artificial means of controlling fire since use of natural breaks would more closely mimic natural ecosystem processes. Use of heavy equipment to construct berms or fire lanes should be minimized to avoid negative impacts to ground-layer vegetation, soil stability, and gopher tortoise burrow systems. Any mechanical fire management practices, particularly plowed fire lanes, should be prohibited within a 7.6-m (25-ft) buffer around known burrow entrances.

Forest management

Silvicultural practices can be compatible with gopher tortoise management. Selective tree harvesting allows the tortoises to remain in a relatively stable canopy habitat. Trees can be harvested to reduce plant density, but harvesting activities should not degrade the understory on which the gopher tortoise feeds. The thinning of dense oaks allows more pine trees to flourish, which produces a more suitable tortoise habitat. Finally, frequent burning in areas with fire-resistant trees (such as longleaf and slash pines) destroys thick understory but allows for the quick regeneration of grasses (Auffenberg and Franz 1982).

Timber harvest that shifts forest stands toward longer rotations and replaces offsite pines and hardwoods with longleaf pine should restore natural fire, hydrologic, and nutrient dynamics in plant communities. Forest management should minimize adverse impacts to wiregrass and other herbaceous ground-layer species.

Hardwood control and pine thinning. In general, the hardwood and pine thinning guidelines recommended for the red-cockaded woodpecker (*Picoides borealis*) on Army lands (U.S. Army Construction Engineering Research Laboratories 1994), to the extent that they restore or promote the maintenance of an open, parklike stand of mature pine-oak forest, should benefit the gopher tortoise. Chemical and mechanical methods of hardwood control should employ best management practices to avoid soil disturbance, destruction of ground-layer vegetation, and nontarget effects of herbicides. Crown closure should be maintained at less than 60 percent to allow adequate sunlight to penetrate to the herbaceous layer. Mechanical logging equipment (e.g., skidders, tractors) should be excluded from a 7.6-m (25-ft) buffer around known burrow entrances.

Mechanical site preparation. Mechanical site preparation (e.g., roller chopping) destroys openings to subterranean burrows, which may result in entrapment of inhabitants. Although gopher tortoises are able to dig out from occluded burrows in deep sandy soils (Diemer and Moler 1982), they may be entrapped by soils with greater clay content (Diemer 1992c). Furthermore, gopher frogs, which often use tortoise burrows as refuges, are unable to excavate their own burrows. Thus, unless they co-occur with tortoises in their burrows, they may become entombed when a site is mechanically disturbed. Site preparation should employ fire where possible rather than mechanical methods such as discing or chopping. Any mechanical site preparation should be excluded from a 7.6-m (25-ft) buffer area around known burrow entrances.

Longleaf pine regeneration. In general, reestablishment of longleaf pine and the regeneration of existing longleaf pine stands would increase the available habitats for the gopher tortoise. Natural regeneration methods should be used in order to avoid high-impact artificial means.

Erosion control

Concerted efforts to reduce and prevent soil erosion within Habitat Management Units (HMUs) for the red-cockaded woodpecker would have a beneficial effect on gopher tortoise habitats by maintaining the integrity of herbaceous layers and gopher tortoise burrow systems. Native vegetation should be used wherever possible, and non-native species should be avoided. Mechanical means of erosion control should maintain the natural contours of the surrounding topography and ensure the integrity of natural hydrologic processes (The Nature Conservancy (TNC) 1995a).

Extractive land uses

Pine straw raking, whether by hand or machine, has been shown to destroy ground-layer vegetation and longleaf pine seedlings and to cause or exacerbate erosion problems.

In the long term, removal of pine straw fuels may also alter fire regimes. All of these potential effects would have negative impacts on gopher tortoises (TNC 1995a).

Training restrictions

Restrictions on training activities within red-cockaded woodpecker HMUs, to the extent that they minimize disturbance to vegetation and soils, should benefit gopher tortoises. Vehicular traffic on roadways should be monitored to reduce soil erosion. Off-road traffic should be minimized because it is highly deleterious to ground cover, soil structure, and hydrologic patterns. Where off-road traffic is unavoidable, it should be prohibited within 7.6 m (25 ft) of known gopher tortoise burrows (TNC 1995a).

Translocation

Relocation has been considered a partial solution to the decline of gopher tortoises. Many foresters, park rangers, tortoise hunters, wildlife officers, and private citizens have played a role in tortoise relocation (Diemer 1987). However, little information is available on the potential of this species for recovery following a major decline in population numbers. Restocking of all ages of tortoises to sites they formerly occupied has been tried in Florida, but the fate of relocated tortoises is unknown (Diemer 1986). In south Georgia, about 40 percent of the tortoises introduced into an area remained in that area 3 years after their introduction (Landers 1981). In north Florida, Diemer (1987) recaptured about 30 percent of relocated tortoises 5 years after their release. Clearly, these studies suggested that many tortoises quickly abandon relocation sites. Cox (1989) used population models to estimate minimum viable population sizes needed for a relocation of tortoises to an unoccupied site. He suggested that the persistence of small populations was longer for mixed populations consisting of subadults and adults than those composed strictly of adults.

Although relocation may be a step toward slowing the gopher tortoise's decline, there are many problems that occur with the process. First, tortoise relocation is controversial, especially since the discovery of an upper respiratory tract disease in some gopher tortoise populations. A proposed testing process of individual tortoises for the disease may prevent translocation of infected tortoises in the future. Second, finding suitable habitat for these animals is not always the top priority. Many times tortoises are taken to state parks and "dumped" because the area is considered to be appropriate habitat. However, these parks often become overpopulated when used too often (Diemer 1987). Third, tortoises will sometimes travel relatively long distances following relocation and return to their home territory. For example, a tortoise released 1.3 km (0.8 mile) from its home territory subsequently returned to within 32 m (105 ft) of its burrow (Diemer 1987). Finally, the potential exists for mixing of gene pools and disruption of indigenous populations. A great deal of thought and preparation should be given to the selection of potential sites (Diemer 1989a).

Other

Because predation on tortoise eggs and hatchlings is great, protection of these stages of their life history has been recommended (Wright 1982). Nests can be protected by

predator-proof enclosures, and in some cases, predators can be removed by hunting or trapping (Landers 1980).

Mitigation standards and requirements for gopher tortoises have developed in Florida over the last decade. Mitigation options include avoidance of individual burrows during development, habitat protection onsite or offsite (usually preserving an area equal to 15 to 25 percent of the occupied tortoise habitat being developed), and relocation of tortoises to suitable habitat (Diemer-Berish 1994).

Because the gopher tortoise is long-lived with delayed sexual maturity and a low-reproductive potential, it is essential to develop adequate management schemes that offer the tortoise protection into the projected future. Management schemes must be formulated to address the needs of the specific population under consideration. Additional conservation measures for the gopher tortoise include establishment of preserves, protection from overharvest, and public education (Landers 1980, Diemer 1986, Diemer-Berish 1994). Conservation efforts to maintain populations of gopher tortoises require significant habitat management practices, even on seemingly "protected" lands owned by States or the Federal Government (McCoy and Mushinsky 1992b).

Management programs

In central Florida, a gopher tortoise management area has recently been developed (Ashton et al. 1994). The site is along the Sumter and Marion county line, where an 809-ha (2,000-acre) retirement and golf community is being developed. The site has been used for farming and ranching for the past 100 years. The goal of the preserve development is to establish and maintain optimal habitats for gopher tortoises, burrowing owls (*Athene cunicularia*), and American kestrels (*Falco sparverius*). Three tortoise preserves, totaling about 61 ha (150 acres), have been created. Each preserve was surrounded by fencing, above and below the ground, to ensure the integrity of the designated preserve sites. These preserves have not been in place for a sufficiently long time period to draw any meaningful conclusions about their success or future. However, the concept of a multiple species approach to onsite mitigation for noncompetitive species is one that should appeal to developers and conservation biologists.

Three recent reports summarize topics in need of further study for North American tortoises (Burke and Cox 1988, Germano and Bury 1994, McCoy 1994). Below is a selected summary of those recommendations that are particularly pertinent to management needs.

a. Quantification of habitat use.

b. Definition of habitat requirements.

c. Determination of what constitutes "quality" habitat.

d. Improving methods to determine tortoise density.

e. Long-term studies to determine temporal variability.

f. Studies on egg and hatchling survivorship.

g. Behavioral studies to determine social interactions and hierarchies.

h. Genetic studies of parentage and selective mate assortment.

i. Genetic studies to determine gene exchange among neighboring populations.

j. Studies on homing and orientation.

k. Studies of the long-term success of relocated tortoises.

l. Studies of diseases and disease transmission among populations.

m. Studies of nutritional requirements and foraging preferences of free ranging tortoises.

Habitat Protection and Species Recovery

Land protection specifications

Landers and Speake (1980) recognized that gopher tortoises can be maintained on small management units, but they proposed that larger units (up to several hundred hectares) would lessen the impact of emigration and mortality. Similarly, Cox et al. (1987) suggested that areas of 10 to 25 ha (25 to 62 acres) of favorable, managed habitat should be set aside for populations occupying lands slated for development. Perhaps the most extensive study of gopher tortoise populations was that conducted by McCoy and Mushinsky (1988). They surveyed a wide variety of sites for tortoises, including some of the largest Federal lands in Florida, as well as numerous, relatively small, unprotected populations of tortoises. They recognized the importance of protecting, if possible, large areas (tens to hundreds of hectares) of gopher tortoise habitat, but emphasized the value of the numerous small isolated populations. McCoy and Mushinsky (1988) pointed out four themes to be considered regarding the protection of gopher tortoises: (a) gopher tortoises function as "keystone species" (one whose presence or absence has a profound effect on the rest of the community) (Campbell and Christman 1982, Eisenberg 1983, Jackson and Milstrey 1989) and therefore merit special consideration in ranking conservation priorities; (b) fragmentation of gopher tortoise populations will continue to increase, and relatively large tracts of habitat will rapidly become rare; (c) conservation of large areas of gopher tortoise habitat is not without risk; and (d) conceiving of fragmented gopher tortoise populations as metapopulations suggests alternate conservation strategies.

Conservation of large areas of land has the potential side effect of creating false security about the future of resident tortoises. Continuous management is critical to these populations; but tortoises occupying extant large conservation areas typically have not been so managed (McCoy and Mushinsky 1992b). Development patterns throughout peninsular Florida are such that it is not practical to set aside even 10 ha (24.7 acres) of land in many places. Populations of tortoises on single large areas of land are vulnerable to stochastic disturbances that may have profound effects on their well-being, effects which are exacerbated if the areas become isolated. The fragility of tortoise demography

in general may make tortoise populations even more vulnerable to extinction from disturbance events than other long-lived vertebrates. McCoy and Mushinsky (1988) believed it unwise to place full emphasis upon the single large area notion of conservation. Rather, they proposed that greater emphasis be placed upon alternate conservation strategies for the gopher tortoise in Florida. They proposed a two-pronged approach. Whenever feasible, large areas of land should be secured, with the stipulation that rigorous management practices are to be employed to monitor continuously the demographic health of the resident population. In parallel with the securing of large areas, they recognized a need to secure large numbers of small areas. Such small areas allow "banking" of genetic diversity, as well as of individuals, for decades or perhaps longer. Management practices tailored to these small areas might even be able to perpetuate a metapopulation for tens of decades or longer.

Dichotomies created between apparently suitable and less-than-suitable gopher tortoise habitats may be misleading and cause some small sites to be dismissed too quickly as unworthy of conservation effort. It seems imperative to view tortoise habitat quality as a dynamic gradient. Area reduction and habitat degradation are two of the greatest threats to the future of tortoise populations: as either increases, the probability of extinction also increases. In combination, the effects of area reduction and habitat degradation likely increase the probability in a synergistic fashion. Hence, while tortoises on large areas of land are in need of continuous monitoring, tortoises on small areas are likely in need of continuous management as well. Each State in which the gopher tortoise resides should serve as steward over these small areas of land to coordinate research efforts designed to address critical questions regarding tortoise management on them and to serve as a clearing house for all translocations of individuals among them. Research priorities concerning management of small areas should include delineation of the potential consequences of tortoise translocation and derivation of methods of increasing site tenacity.

Recovery plan

The gopher tortoise recovery plan (USFWS 1990) was developed for the western population, but portions are also applicable to the eastern population. The immediate objectives of the recovery plan are to prevent this population from becoming endangered by stabilizing or enhancing the existing population. Unfortunately, the majority of existing habitat occurs on private lands. Under Section 7 of the Endangered Species Act of 1973, the USFWS requires that a consultation occur whenever any proposed action of another agency may affect a listed species.

Recovery criteria that would result in the prevention of endangered status and subsequent delisting of the western population, respectively, include:

a. Having an average of five gopher tortoise burrows/hectare on deep sandy soils (≥1.52 m (4.9 ft)) for 30 years on the Desoto National Forest. This would equate to an estimated population of 22,400 tortoises on 7,343 ha (18,145 acres) of suitable habitat.

b. Have an average of three tortoises/hectare on deep sandy soils (≥1.52 m) on private lands. This would equate to 34,000 tortoises on 18,594 ha (45,947 acres).

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13. ABSTRACT *(Maximum 200 words)*

The gopher tortoise (*Gopherus polyphemus*) is the only tortoise that occurs east of the Mississippi River. The U.S. Fish and Wildlife Service has separated the species into two main populations. The western population (southwest Mississippi and southeast Louisiana) is Federally listed as threatened; the eastern population, which occurs in southern Alabama and Georgia, extreme southwestern South Carolina, and most of Florida, is a former candidate for listing as threatened. Gopher tortoises occupy a wide range of open, upland habitats with a well-drained, deep sandy substrate, primarily longleaf pine-xerophytic oak woodlands (sandhills). They have been documented on several military installations in the Southeast. This report is one of a series of "Species Profiles" being developed for threatened, endangered, and sensitive species inhabiting southeastern United States plant communities. The work is being conducted as part of the Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP). The report is designed to supplement information provided in plant community management reports for major United States plant communities found on military installations. Information provided on the gopher tortoise includes status, life history and ecology, habitat requirements, impacts and cause of decline, management and protection, and inventory and monitoring.

14. SUBJECT TERMS

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Management techniques	Species profile	

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