MANAGEMENT NEEDS OF SANDHILL REPTILES IN SOUTHERN GEORGIA

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Abstract: Habitat use by the gopher tortoise (*Gopherus polyphemus*), eastern indigo snake (*Drymarchon corais couperi*), and associated species was studied in southern Georgia. Tortoises colonized sites where sand depth typically exceeded 1 m, and generally moved within areas less than 4 ha each year. The greatest population density (15.8/ha) was in longleaf pine (*Pinus palustris*)—scrub oak (*Quercus* spp.) stands burned every 2-4 years. Thirty other vertebrate species were observed using tortoise burrows, and den size was evidently a factor in selection by some. All radio-instrumented indigo snakes used sandhills during winter and 94 percent of the winter dens were tortoise burrows; they also nested, foraged, and denned in burrows during other seasons and frequented clearings and windrowed areas. In slash pine (*Pinus elliottii*) plantations frequently burned, herbaceous biomass was 2.3 times as great, tortoise density was 3.1 times as great, and indigo snake use was 2.8 times as great as in an adjacent natural area where most longleaf pine had been harvested and fire seldom used. Recommended recovery of such areas includes judicious thinning of scrub oaks and re-establishing the pine component to produce needle cast for carrying fire. The remaining forested sandhill communities are increasingly important and can be maintained only with active management.

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The xeric wildlife habitat across the southeastern Coastal Plain includes a complex of fire-adapted communities which are tied to droughty, sandy soils. In Georgia, xeric sites occur intermittently in the Fall Line Hills and in portions of the middle and lower Coastal Plain, mostly parallel to and east of rivers and major creeks. Vegetation is broadly classified as oak-pine-heath (Bozeman 1971) or dwarf oak-pine forest (Wharton 1978), and has also been described as dry pine barrens (Harper 1906). The community is often referred to as longleaf pine-scrub oak sandhills. Existing evidence indicates a dependence of this community on natural fire during summer, with an average burn frequency of once every 5 to 10 years (Wharton 1978).

Sandhills provide year-round or seasonal habitat for a variety of vertebrates, many of which have adapted to the hot summers and cool winters through use of burrows. The gopher tortoise, a colonial species, is often the primary grazer. Accumulated fecal material in its burrow attracts many insects which are eaten by amphibians (e.g. the gopher frog, *Rana areolata*) and other vertebrates. These commensal species are major food sources of certain snakes. Sandhills support several rare amphibians and reptiles, some of which are considered threatened (Speake and Mount 1973, Federal Register Vol. 43 No. 52:11082-11093).

In recent years, interest in this community in southern Georgia has greatly increased. Wharton (1978) pointed out the need for preserving the habitat type, in view of its ecological importance and diminished distribution. The loss and alteration of habitat was identified as a major cause of population decline of the gopher tortoise (Auffenberg and Franz 1975) and indigo snake (Speake et al. 1978). The status of most other associated animals in the state is largely unknown.

The remaining forested, xeric sites are increasingly valuable in an ecological sense because the type is rapidly being converted to croplands and home sites. For several species basic ecological data are now available, but specific plans for managing habitat have not been developed. This report draws from intensive studies of the gopher tortoise and indigo snake and empirical data on associated species gathered during those studies. Major objectives are to (1) present data on habitat use by certain sandhill vertebrates, (2) compare habitat components in natural and cut-over sandhill stands with pine plantations, and (3) present management recommendations for sandhill wildlife habitat.

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METHODS

Silver Lake Station is a 1400-ha portion of International Paper Company's Southlands Experiment Forest located in Decatur County, southwestern Georgia. The dominant forest type is longleaf pine (867 ha). Natural sandhill vegetation forms 210 ha, including scattered longleaf pines and a mixture of bluejack (*Quercus incana*), sand post (*Q. margaretta*), turkey (*Q. laevis*), and twin live (*Q. geminata*) oaks. An additional sandhill area, which was previously forested with natural longleaf pine-scrub oak vegetation, now supports slash pine (98 ha); that area was site-prepared by double-chopping and debris burning, then planted (1964) on a 2.5 x 3.1 m spacing. Limestone depressions forming ponds or supporting hydric tree species (225 ha) are also common, and most have been permanently or seasonally flooded since completion of the Lake Seminole dam in the late 1950's. All natural drainage is to these depressions, and there are no streams or associated bottomland vegetation.

On upland sites groundstory vegetation is predominately wiregrass (*Aristida stricta*), bracken fern (*Pteridium aquilinum*) and running oak (*Q. pumila*). Open habitat conditions have been maintained with annual late-winter burning for approximately 20 years. The burning program is designed to manage for bobwhites (*Colinus virginianus*), the featured game species on the area. Gopher tortoise colonies are located mainly on xeric sand ridges, where herbs and shrubs grow sparsely on the excessively-drained soils of the Lakeland and Troup series. Many other species of reptiles and amphibians are common on dry sites, but the indigo snake is extremely rare; all non-game species are protected. Elevation in this area ranges from 24 to 31 m above sea level. Average maximum temperature for the summer is 32° C, and annual rainfall averages 127 cm.

Field work was also conducted near Tifton, Georgia, on a 2756-ha tract owned by ITT-Rayonier Corporation that has been designated a Snake Sanctuary. Access to the area is restricted to protect reptiles, especially the indigo snake which is relatively common there. Gopher tortoises are numerous throughout the sandhill community. This tract is also used for hunting bobwhites and white-tailed deer (*Odocoileus virginianus*). The area lies on the eastern side of the Alapaha River in Irwin County, with the river swamp forming its western boundary. Mixed agricultural land borders it on the east.

The study area is primarily sandhill habitat formerly dominated by longleaf pine and turkey oak, with saw palmetto (*Serenoa repens*) and wiregrass as the dominant understory. Most of the longleaf pine-scrub oak type was clearcut, site-prepared by dragging an anchor chain and windrowing the debris, then planted to slash pine in the mid-1960's. Small areas of the original habitat remain relatively unaltered except for removal of the larger longleaf pines. The site-prepared habitat has been prescribed burned at biennial intervals in recent years and is now dominated by slash pine, turkey oak, twin live oak, bluejack oak and sand post oak. Wiregrass, broomsedge (*Andropogon virginicus*), saw palmetto and blackberry (*Rubus* spp.) are important understory species. Soils are predominantly droughty sands of the Lakeland and Kershaw series.

Mesic hammock is found in some areas along the edge of the river swamp, and small cypress (*Taxodium ascendens*) ponds are scattered over the area. Streambottom thickets dissect the sandhills along numerous stream courses. About 18 percent of the area is in low, slash pine plantations with understories of gallberry (*Ilex glabra*), blackberry and wax myrtle (*Myrica cerifera*). Elevation above sea level ranges from 67 to 76 m. During the summer months the average maximum temperature is approximately 33° C, and rainfall averages 103 cm annually.

For habitat evaluation, a pair of areas was chosen which represented the most natural vs most intensively managed stands available on each of the 2 study areas. At Silver Lake Station a 16-year-old slash pine plantation and a natural longleaf pine-scrub oak stand were sampled. The plantation had been prescribed burned annually for 8 years and the natural stand, though subjected to fire annually, carried fire every 2 to 4 years. On the Rayonier Snake Sanctuary a 16-year-old slash pine plantation burned every 2 years, and a cut-over longleaf pine-scrub oak stand which had not been burned for 8 years, were chosen. This latter stand, where much of the longleaf pine had been harvested and fire seldom used in management, was in a condition typical of most "natural" sandhills we observed during distribution studies of the gopher tortoise and indigo snake in Georgia.

All selected stands were located on Lakeland sands, the most prevalent droughty soil on both study areas. Within each habitat type an area was chosen which contained a breeding tortoise colony (evidenced by nests or hatchlings) and which received use by indigo snakes. In each vegetation type, 20 subplots (0.64 x 1.56 m) were established; all green herbaceous plants and low woody plants which produce fleshy fruits were clipped and weighed (wet basis). A 100 x 200 m plot, encompassing subplots used for lesser vegetation sampling, was established for overstory analysis. For each tree $\geq$ 5 cm in diameter at breast height (dbh), the total height and dbh were recorded by species.

On the Silver Lake Station, gopher tortoises were captured by hand or in pit-fall traps imbedded in front of their dens. Capture effort was concentrated in 6 major colony areas, but other tortoises outside these colonies were utilized for study as they were encountered incidently. Each tortoise was individually marked using notches on the marginal shields, then released at the capture point. Larger specimens (carapace length $>$ 20 cm) in sample colonies were also color-coded by spot-painting on the carapace. Subsequent locations from March 1978 through May 1980 provided data on movements and an estimate of the general area utilized by each colony group. In one of the colonies, 13 adults were monitored throughout an entire activity season (1979) through radio telemetry; the area covered by this closely associated group provided a more detailed example of the total range required by a breeding colony unit. Description of telemetry equipment and ranges of individual tortoises are presented by McRae et al. (1981).

Gopher tortoise population density on both study areas was estimated using a technique developed by Auffenberg and Franz (1975). This technique involved counting active burrows within 15 x 150 m belt transects and applying a correction factor (0.614) for

number of individuals per count of burrows. Ten such transects were conducted in each of the habitats where plants were sampled.

Studies of growth and sexual maturity (Landers et al. 1981) and reproduction (Landers et al. 1980) were conducted on the Silver Lake Station. Also during early June of 1977 and 1978 an intensive search for tortoise nests was conducted on the Rayonier area.

Field work on the indigo snake was conducted on the Rayonier Snake Sanctuary. In September 1976, an intensive search for specimens was begun. Eighteen adults were captured as they were crossing roads, moving in forested areas, or denning in tortoise burrows. Thirty-one other adults from various localities in southern Georgia or northern Florida were brought to the area. Each of the 49 snakes was uniquely marked by clipping or branding one of the subcaudal scutes and attaching a numbered fish-anchor tag laterally along the tail. Of these specimens, 37 were instrumented with radio transmitters before they were released. Telemetry equipment and procedures are described by Speake et al. (1979). Locations of marked and telemetered snakes provided data on habitat use. As a measure of habitat preference, relative use was determined for natural longleaf pine-scrub oak stands and slash pine plantations. Food habits data were collected from stomach contents regurgitated by captured snakes.

During field work on both study areas, data were gathered on other vertebrates which utilize sandhill habitat, especially those which use burrows. Records were obtained on species captured in pit-fall traps or in excavated burrows, or otherwise captured or seen in and around burrows. In each case, the width of the burrow used was measured at a point 0.6 m down in the burrow entrance. When possible, the nature of activity or use (e.g. nesting, feeding, escaping from predators, etc.) was also recorded for these species.

RESULTS AND DISCUSSION

Habitat Composition

The composition and density of the overstory was quite varied among habitats sampled (Table 1). Site preparation led to a pronounced reduction of scrub oaks, more so in plantations preceded by chopping (Silver Lake Station) than by chaining (Rayonier Snake Sanctuary). However, at least some of this reduction must be attributed to frequent prescribed burning, which prevents some oak sprouts from attaining fire-resistant size, and to competition with the faster growing pines. The latter effect is mediated by the decrease in stocking as compared to the original planting rate. A high degree of mortality and stunting of pines is common in slash pine plantations established on sandhills (Ralston and McGee 1962), and our areas were not exceptional in this respect. Therefore, the canopy is non-uniform in coverage, and openings with scrub oaks are common.

The notable differences in the two longleaf pine-scrub oak areas sampled largely reflect fire frequency. In the Silver Lake area, fire carried through sandhills once every 2 to 4 years. Fire kept most oaks in the low sprout or sapling stage ($<$ 5 cm dbh) and often damaged larger ones, causing them to deteriorate and eventually fall. Scrub oaks formed a patchy multi-layered canopy because of the reduced density of hardwood stems and pruning effects of fire on limbs of larger trees. On the Rayonier area some hardwoods were unusually large in dbh and height. The latest attempt to prescribe burn that area was 8 years prior to sampling; this burn was conducted concurrently with one in the adjacent plantation used in this study (T. Sandifer, pers. comm.). From examination of the site it was evident that fire (introduced in late winter) had little effect on hardwoods. The infrequent occurrence of blackened tree trunks and presence of large shrubs indicated that the fire did not carry through much of the stand. Most oaks had long since reached fire resistant size, and had produced a mat of leaf litter on the ground which retarded spread of fire. Fire exclusion, resulting in scrub oak maturity and litter accumulation, is a major cause of habitat degradation in the case of the gopher tortoise (Franz and Auffen-

Table 1. Overstory tree species in sandhill habitats of southern Georgia.

Tree Species[1]	Rayonier Snake Sanctuary						Silver Lake Station					
	Slash Pine Plantation			Longleaf Pine-Scrub Oak			Longleaf Pine-Scrub Oak			Slash Pine Plantation		
	No./ha	$\bar{x}$dbh (cm)	$\bar{x}$ht(m)	No./ha	$\bar{x}$dbh (cm)	$\bar{x}$ht(m)	No./ha	$\bar{x}$dbh (cm)	$\bar{x}$ht(m)	No./ha	$\bar{x}$dbh (cm)	$\bar{x}$ht(m)
Pines												
Slash	478	10.9	7.3							722	10.7	8.8
Longleaf				6	12.9	9.2	317	12.1	9.9			
Oaks												
Turkey	350	6.4	5.2	467	9.8	4.9	300	11.4	6.4	139	8.2	7.2
Bluejack	100	6.7	5.3	111	7.3	3.9	50	7.1	5.6	39	8.3	7.0
Sand Post	17	5.9	5.3	200	6.7	4.5	17	5.0	5.3	11	8.4	7.2
Twin Live	22	6.9	4.3	139	6.9	5.2	5	6.2	4.0	22	8.0	6.9
All Oaks	489	6.5	5.2	917	8.4	4.7	372	10.5	6.2	211	8.2	7.1
TOTAL	978	—	—	922	—	—	689	—	—	933	—	—

[1]Only trees with dbh $\geq$ 5 cm are included.

berg 1974). The very low density of longleaf pine, due to past harvesting, was thought to be an additional factor in the minimal impact of the burn; needle cast is important in carrying fire and thus in maintaining this community.

The understory biomass and species composition was a reflection of the degree of disturbance (by fire and previous site preparation) and overstory development (Table 2). On both study areas, species richness of herbs in pine plantations (49 at Silver Lake Station, 41 at Rayonier Snake Sanctuary) was greater than in companion plots within longleaf pine-scrub oak stands (43 and 33, respectively). This difference was attributed to effects of mechanical site preparation which reduces coverage of mat-forming perennial herbs (e.g. wiregrass) and hardwoods, and favors a variety of other herbs (Buckner et al. 1979). Also, total plant biomass in plantations at both sites was significantly ($P < 0.05$) greater than in relatively natural stands.

At Silver Lake Station, pine plantations included far less biomass of grasses and much more of composites (especially silk-grass, *Heterotheca graminifolia*) than longleaf pine-scrub oak stands. Plantation establishment, preceded by double chopping, had eliminated wiregrass and increased broad-leaf grasses (e.g. *Panicum* spp., *Paspalum* spp.) to 22 g/m^2, compared to that in natural stands of 12 g/m^2. Members of the Scrophulariaceae, notably *Gerardia* spp., were much more abundant in plantations than in natural stands. Biomass of legumes (Fabaceae) was similar in the two stand types, presumably because of frequent burning in both areas.

On the Rayonier study area, the lower numbers of plants and overall diversity in natural stands as compared to plantations were due primarily to greater competition from scrub oaks in the former. The canopy was almost completely closed in the longleaf-scrub oak type. It is doubtful that prescribed burning, if applied under normal conditions in late winter, would have appreciably altered the groundstory due to reduced potential for carrying fire and for sunlight penetration. Of the 16 major plant groups, 13 were represented in greater biomass within plantations and 2 were about equal to that on the adjacent, longleaf pine-scrub oak ridge. The only group with greater biomass in the natural stand was the rose family (Rosaceae) represented by gopher apple (*Chrysobalanus oblongifolius*) at 28 g/m^2; this plant had shown very little recovery (4 g/m^2) from site preparation on the planted area. Major groups that were apparently stimulated by past soil disturbance in plantations were composites and dayflowers (*Commelina* spp.).

Habitat Use

Gopher tortoise colonies were found only on the driest sites in the study areas. Soils in such areas were either Troup, Lakeland, or Kershaw where sand depth exceeded 1 m. In Georgia this species typically occurs in deep sands of the late Tertiary and Recent deposits, originally forested with the longleaf pine-turkey oak type (Franz and Auffenberg 1974).

Within areas of suitable habitat, most tortoises occurred in colonies where burrow density was high and large areas between colonies supported only isolated individuals or small groups. In the habitats sampled (Table 3), burrow density was greatest where burning was frequent, especially in the natural stand containing a significant longleaf pine component (Silver Lake Station). Plantations on both areas also contained high population densities due to the wide spacing of trees and pine mortality (noted earlier) and effects of burning. At the Rayonier Snake Sanctuary, density of tortoises in the natural stand (3.3/ha) was significantly less ($P < 0.05$) than in the adjacent plantation (10.1/ha).

Tortoise distribution was dependent on food availability. The home range of gopher tortoises is inversely related to the density of plant ground cover (Auffenberg and Iverson 1979). This grazing herbivore consumes large quantities of groundstory plants.

Table 2. Herbaceous plants in sandhill habitats of southern Georgia.

Plant Family	Rayonier Snake Sanctuary				Silver Lake Station			
	Slash Pine Plantation		Longleaf Pine-Scrub Oak		Longleaf Pine-Scrub Oak		Slash Pine Plantation	
	g/10m²	% Occ	g/10m²	% Occ	g/10m²	% Occ	g/10m²	% Occ
Poaceae (grass)	611	100	191	100	740	100	215	100
Asteraceae (composite)	259	100	9	50	283	100	1438	100
Acanthaceae (acanthus)	162	95	12	90	50	90	10	25
Fabaceae (legume)	102	80	40	35	99	95	74	100
Rosaceae (rose)	85	55	279	75	0	0	41	65
Commelinaceae (dayflower)	50	55	13	30	1	15	7	50
Cactaceae (prickly pear)	43	55	44	25	0	0	2	5
Euphorbiaceae (spurge)	31	90	21	95	8	45	13	95
Brassicaceae (mustard)	20	95	2	15	0	0	0	0
Polygonaceae (smartweed)	18	20	1	5	29	40	0	0
Cyperaceae (sedge)	9	25	1	15	32	75	7	45
Convolvulaceae (morning glory)	7	40	2	15	4	15	11	30
Cistaceae (rock rose)	4	15	1	5	0	0	41	60
Scrophulariaceae (scroph)	2	10	0	0	9	10	98	70
Lamiaceae (mint)	1	25	1	5	15	15	1	5
Rubiaceae (poor Joe)	1	10	0	0	1	10	23	60
TOTAL[1]	1420	100	618	100	1272	100	1997	100

[1]Includes plant groups in addition to those listed.

Table 3. Relative use of sandhill habitats by gopher tortoises and eastern indigo snakes in southern Georgia.

	Rayonier Snake Sanctuary		Silver Lake Station	
No. Locations	Slash Pine Plantation	Longleaf Pine-Scrub Oak	Longleaf Pine-Scrub Oak	Slash Pine Plantation
Gopher Tortoise[1]	10.1	3.3	15.8	9.3
Indigo Snake[2]	108	39	-	-
Indigo Snake[3]	0.20	0.07	-	-

[1]Number per hectare, calculated by multiplying conversion factor (.614) times number of active burrows (after Auffenberg and Franz 1975).

[2]Number of total radio locations of 5 snakes using a 36-ha natural stand adjacent to a section of pine plantation of equal size. These areas were used for plant sampling and tortoise density estimates.

[3]Relative index of use for the two xeric-site habitats, calculated by dividing the total number of separate locations for 37 adult snakes by the number of hectares in each type.

Major foods are wiregrass (Fisher 1917), broad-leaf grasses (Carr 1940), and succulent forbs and fruits (Cockran 1952). Silk grass and legumes are also important foods (our observations). Low food availability was obviously a factor in the low population density in the cut-over longleaf pine-scrub oak area. Even wiregrass clumps were scattered, and over half of the culms encountered in plots were dead. Herbs were suppressed by accumulated oak leaves, other litter and shading.

Another factor that possibly contributed to low tortoise numbers in that area was inadequate nesting habitat. Eggs are typically laid in the burrow mound or other sunny spot; nearly full exposure to sunlight is required for incubation (Hallinan 1923) and females will move long distances to find suitable spots at the time of nesting (Landers et al. 1980a). In early June, the peak egg-laying period, an intensive search for nests revealed 8 in the sample plots in the plantation and only 2 in the more shaded habitat of the natural stand (Rayonier area).

Micro-site characteristics are important in stability of tortoise colonies. Within a colony, clusters or activity centers of closely associated males and females exist. Other than short range (usually < 30 m) feeding forays from the burrow, most movements are related to breeding behavior during spring and early summer, though some relocations in late summer and fall may be related to local food depletion within activity centers (McRae et al. 1981). The sedentary nature of gopher tortoises is apparent from the limited area covered during an activity period (Table 4). From spring through fall, the mean percentage increase in range of monitored colony units was 434 percent. Normal yearly movements of each group ($\bar{x} = 10$ adults), including those associated with social interaction, occurred in an area less than 4 ha. Juveniles were even more sedentary and typically used the same burrow throughout the season. However, long-range movements did occur (mostly by males), though very infrequently. For example, on the Silver Lake study area 5 adult males were known to move more than 1 km from their original colonies. Seven other adults (6 males, 1 female) moved completely off the study areas at distances of 0.8 to 4.8

Table 4. Area covered by gopher tortoise colony groups in one activity season, 1978 or 1979.

Tortoise Group	Individuals M	F	(n) J	Locations[1] (n)	Initial Group Area (ha) Spring Capture	Total Group Area (ha) Spring-Fall
1	6	4	3	49	1.62	3.41
2	7	3	6	39	.77	2.69
3	3	3	0	23	.61	3.66
4	9	4	1	45	.40	1.55
5	5	3	4	28	.45	2.38
6	8	5	4	2483	.69	3.63

[1]Groups 1-5 and juveniles in group 6 were monitored using capture-recapture and sightings. Adults in group 6 were studied using radio telemetry.

km from the point of initial capture. In these cases, they were recaptured while moving along dirt roads or in cultivated fields.

During this study, 12 tortoises (all unmarked) were found killed by vehicles along a 2.5 km strip of paved road bordering the Silver Lake Station. This demonstrates the importance of highway mortality as a major decimating factor, as pointed out by Franz and Auffenberg (1978). Recovery of depleted populations is inhibited by a very low reproductive rate and slow growth to sexual maturity; it is clear that this species cannot sustain extensive harvest, a common problem in certain areas of the Southeast (Landers et al. 1980a,b).

The indigo snake is much less sedentary than the gopher tortoise. Many individuals make seasonal long-range movements away from xeric habitat into agricultural fields and streambottom thickets during summer (Speake et al. 1978). However, all individuals ($n = 24$) studied during winter on the Rayonier area selected the xeric sandhills as winter habitat. This demonstrates their dependence on this habitat type, at least in this northern portion of their range. These 24 snakes were located in a total of 107 different winter dens of which 101 (94%) were tortoise burrows. Four percent were in windrows and 2 percent were stump holes. The indigo snake is active throughout the winter when temperatures permit. Since the species does not hibernate, the availability of deep dens that do not flood (e.g. gopher tortoise burrows on the sandhills) are essential for winter survival.

During the study xeric habitats were used more frequently than others. Total separate radio locations in xeric types were about 3 times as frequent as in mesic or hydric types per unit of area. The xeric slash pine plantation type was preferred to the longleaf pine undisturbed habitat (Table 3). The paired adjacent areas used for plant sampling were compared for snake use since the movements of five indigo snakes had been monitored there and both types were available for the snakes to use. During the period that the radios were operating 108 locations were in the slash pine type and only 39 were in the longleaf pine-scrub oak type. Chi-square analysis indicated a highly significant preference for the slash pine habitat ($P < 0.001$). One of these specimens was a gravid female that explored numerous sites in both habitats and then laid her eggs in a tortoise burrow within the slash pine plantation.

Preference of the indigo snakes for the xeric slash pine plantation over the more natural longleaf pine-scrub oak habitat probably is related to its more open condition. Greater abundance and diversity of herbaceous vegetation was brought about by site preparation and prescribed burning (Table 2), supported a denser gopher tortoise population (Table 3), and thus indirectly produced more denning and feeding sites for snakes. In addition to tortoise burrows, the windrows of debris produced by site preparation were attractive to indigo snakes as hiding and foraging areas. One large windrow and the adjacent site prepared area were very attractive to indigo snakes one year after intensive site preparation and planting to pine. Six instrumented snakes stayed in the windrow or a small site-prepared area nearby for at least 2 months during early fall of 1979. Other windrows in older plantations were also heavily utilized.

Indigo snakes feed on a wide variety of vertebrates (Mount 1975) including snakes, frogs, toads, small mammals, birds, turtles and fish. Data on regurgitated food items were obtained from 4 south Georgia specimens (1 sample from each snake) during this study. Items identified followed by the number of occurrences were as follows: gopher tortoise hatchling—4; eastern diamondback rattlesnake (*Crotalus adamanteus*)—3; cottonmouth (*Agkistrodon piscivorus*)—1: house mouse (*Mus musculus*)—1: eastern harvest mouse (*Reithrodontomys humulis*)—1. All of the prey species except the cottonmouth would be expected to occur in the cover of windrows or tortoise burrows.

Since indigo snakes tend to concentrate in tortoise burrows, especially during winter,

they are vulnerable to gassing and collection by snake hunters. Protection for this species is therefore essential (Speake and Mount 1973).

During the course of field work on the gopher tortoise and indigo snake, 16 other reptile (Table 5) or amphibian (Table 6) species were found using tortoise burrows. The most commonly occurring burrow associates were various species of snakes and toads. In many cases, it appeared that the size of the den was a factor in selection by commensal species. For example, of 6 burrows of tortoise hatchlings excavated in one small area, 3 contained one of the following immature burrow associates each: 1 gopher frog, 1 Florida pine snake (*Pituophis melanoleucus mugitus*), and 1 Fowler's toad (*Bufo woodhousei fowleri*); 12 other immatures of these species, collectively, were found in other small burrows but only adults were found in large burrows. Similarly, large eastern coachwhips (*Masticophis f. flagellum*) and eastern diamondback rattlesnakes were found in large burrows, while smaller specimens were captured most commonly in smaller ones. Other examples of possible size selection for dens are indicated in Table 5.

The nature of burrow use could not always be determined. However, in 5 instances snakes were seen in the process of ingesting prey, and anurans and lizards were observed feeding on insects in 3 and 2 cases, respectively. In one case an eastern box turtle (*Terrapene c. carolina*) was seen eating mushrooms (Basidiomycetes) and a beetle (Scarabaeidae) approximately 1 m down in a large burrow. Quite often, these vertebrates were inactive, especially during the hot summer months. Also, inactive specimens of all snakes listed in Table 5 except the southern black racer (*Coluber constrictor priapus*) were found in tortoise burrows excavated during winter.

Use of burrows by certain mammals and birds also was noted. Old field mice (*Peromyscus polionotus*), cotton mice (*P. gossypinus*), house mice, and cotton rats (*Sigmodon hispidus*) were common residents. Cottontail rabbits (*Sylvilagus floridanus*) used large vacant burrows for nesting (2 sightings); they also utilized dens for escape from avian predators (4 sightings), coyotes (*Canis latrans*) (1 sighting), and from fire (1 sighting). Foxes (both *Vulpes vulpes* and *Urocyon cinereoargenteus*) were known to enlarge them for dens, as were coyotes, raccoons (*Procyon lotor*), opossums (*Didelphis marsupialis*), and striped skunks (*Mephitis mephitis*). On four occasions bobwhites were seen escaping from avian predators, and on 3 separate occasions Carolina wrens (*Thryothorus ludovicianus*) were seen feeding on insects in gopher tortoise burrows.

The diverse animal life that inhabits tortoise burrows has been well documented in Florida. Many kinds of invertebrates are residents, and some are found exclusively in tortoise burrows (Hubbard 1894). The burrows are also used by some vertebrates that within the Southeast are found mainly in Florida such as burrowing owls (*Speotyto cunicularia*) (Allen and Neill 1951); as many as 32 species are known to use these dens to some extent (Hutt 1967).

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Data from this study demonstrate the importance of early successional plant components to many inhabitants of the sandhills. Density of gopher tortoise populations is closely related to biomass of herbaceous food plants. A sparse tree canopy and relatively open (litter-free) ground condition are important for food production and nesting. Breeding groups are closely tied to colony areas where, in good habitat, most movement occurs within an area a few hectares in size. Viable populations can therefore be maintained on small management units. However, larger areas of several hundred hectares would be more desirable to lessen the impact of emigration and mortality (e.g. from highway traffic). Because of the extremely low reproductive rate, slow growth to sexual maturity, and extent of habitat loss, it is recommended that the gopher tortoise be protected from harvest in Georgia.

Table 5. Reptiles found in burrows during studies of the gopher tortoise and indigo snake in Georgia sandhills.

Species	Occ.[1] by Burrow Width Class (cm) < 10	11-20	20 >	Nature of Use[2]
Fla. pine snake *(Pituophis melanoleucus mugitus)*	6 J	2 J	15 A	2 F, 2 D, 19 Ac
E. diamondback rattlesnake *Crotalus adamanteus)*		1 J	22 A	1F, 2D, 1F, 19 Ac
Dusky pigmy rattlesnake *(Sistrurus miliarius barbouri)*	1 A	2 A		1 D, 2 Ac
E. coachwhip *(Masticophis f. flagellum)*	2 J	1J	13 A	1 N, 1 D, 14 Ac
E. hognose *(Heterodon platyrhinos)*	1 A	2 A		2 F, 1 D
S. black racer *(Coluber constrictor priapus)*			6 A	2 E, 4 Ac
E. box turtle *Terrapene c. carolina*			3 A	1 F, 2 Ac
Six-lined racerunner *(Cnemidophorus sexlineatus)*	1 J	4 A	9 A	1 N, 1 F, 12 Ac
Broad-head skink *(Eumeces laticeps)*		2 A	2 A	1 F, 3 Ac

[1]Occurrence of juveniles (J) and adults (A) in tortoise burrows.

[2]Nature of use: feeding (F), nesting (N), escaping (E), denning during winter dormancy (D), or active (Ac) in the burrow but nature of activity unknown.

Table 6. Amphibians found in gopher tortoise burrows in Georgia sandhills.

Species	Occ.[1] by Width Class (cm) <10	11-20	20>	Nature of Use[2]
Newt *(Notophthalmus viridescens)*			1 A	Ac
Fowler's toad *(Bufo woodhousei fowleri)*	3 J		11 A	1 F, 13 Ac
S. toad *(B. terrestris)*	2 J		4 A	1 F, 5 Ac
American toad *(B. americanus)*			1 A	1 Ac
E. spadefood toad *(Scaphiopus holbrooki)*			1 A	Ac
E. narrow-mouthed toad *(Gastrophryne carolinensis)*			3A	Ac
Gopher frog *(Rana areolata)*	3 J	1 A	34 A	1 F, 37 Ac

[1]Occurrence of juveniles (J) and adults (A) in tortoise burrows.

[2]Nature of use: feeding (F) or active (Ac) in burrows but nature of activity unknown.

Gopher burrows are important to many other vertebrates for nesting, feeding, escaping from predator and fire, and protection from adverse weather conditions, especially during periods of intense summer heat and cold winter. It appears that a variety of den sizes is important to accommodate the various sizes of burrow associates. Some species, such as the gopher frog, are rarely found outside the burrows and their welfare is more directly dependent on the tortoise and the habitat conditions which benefit it. The total habitat needs for most reptile and amphibian associates found during this study are unknown, but it is clear that at least some of their requirements are provided by tortoise habitat management.

The indigo snake feeds largely on other snakes, small tortoises, small mammals, and amphibians, and appears to be at the top of the insect-amphibian-reptile food chain of the sandhills. In Georgia, this species requires many tortoise burrows over a large home range, especially during winter. Its distribution in the state is limited to areas with extensive sandhills interspersed with wetland habitats such as drainageways, river swamps, and cypress ponds.

Judging from habitat use of the gopher tortoise, a primary grazer: the indigo snake, a far-ranging predator: and observations of many other vertebrates using tortoise burrows, habitat management needs are apparent. In longleaf pine-scrub oak stands, the hardwood component should be judiciously controlled. A high density of oaks is acceptable, if the canopy is kept open and most stems are in the small diameter classes. Where trees are too dense, hardwoods should be thinned by mechanical or chemical means, or if feasible by a hot summer burn. Since this community originally included longleaf pines, a pine component should be re-established where it has been reduced in the past: pine needles are

important in carrying fire in the sparse understory. Where ground fuel is adequate in natural stands, summer burn frequency should be at least once every 5 to 10 years, but intervals of 2 to 4 years between winter burns has been shown in this study to be beneficial.

Slash pine plantations, if properly managed, can support viable sandhill reptile and amphibian populations. Stands dominated by pine but which contained a significant scrub oak component were found to support breeding gopher tortoise colonies and receive use by indigo snakes and many associated species. Windrows within clearcuts and plantations were also found to be used heavily by indigo snakes. Therefore, these brush piles should be left intact and not flattened during the rotation, a common practice for cosmetic purposes. Windrows are also beneficial to bobwhites (Brunswig and Johnson 1972), deer (Hazel et al. 1977) and other animals.

While commercial thinning was not evaluated during this study, it is clear that it would be beneficial in opening the canopy and increasing understory development. In consideration for burrow-dwelling animals in forest management, it is recommended that low intensity site preparation (e.g. anchor chaining) be used rather than more intensive methods (e.g. root raking). The most important factor in plantation management is prescribed burning. Due to the great biomass in the understory, it is recommended that burning be practiced annually or biennially.

The habitat conditions outlined here which favor sandhill reptiles are produced by management schemes for bobwhites and white-tailed deer. Therefore, management for game animals on these xeric sites can be coordinated with that for burrow-dwelling non-game animals, if adequate protection from exploitation of the latter is provided.

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