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Report T-669
Status of the Gopher Tortoise in Everglades National Park

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I 29.95:T-669

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June 1982

FLORIDA INTERNATIONAL UNIVERSITY
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MAY 15 1991

Kushlan, James A., and Frank J. Mazzotti. 1982. Status of the Gopher Tortoise in Everglades National Park. South Florida Research Center Report T-669. 15 pp.

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INTRODUCTION

The gopher tortoise (Gopherus polyphemus) is widely distributed along the southeastern coastal plain of North America. The core of its population is in southern Alabama and Georgia and in northern and central Florida, where it inhabits sandy, xeric habitats, especially pine and beach scrub (Ernst and Barbour 1972). Population segments are scattered in southern Florida (Figure 1) where suitable habitat is confined to the coasts. On the west coast, tortoises occupy high sandy islands as far south as Marco. On the east coast, they occur in sandy soil and sandy pockets in the limestone bedrock of the eastern coastal ridge as far south as Cutler (Auffenberg 1978). These southernmost population segments are now extinct, or nearly so, because of loss of habitat to development, and the tortoise is considered to be a threatened species in the state of Florida (Auffenberg 1978).

The southernmost population of the species occupies the beach dunes of Cape Sable, the southwestern tip of the Florida peninsula (Figure 1). Gopher tortoises on Cape Sable are notable because they are disjunct from current and historically-occurring populations further north. Despite this population being the only one remaining in extreme southern Florida, its status and characteristics are nearly unknown. The literature contains only a few brief comments noting its existence (Carr and Goin 1955, Auffenberg 1978) and no account of its habitat use or population structure. The purpose of the current study was to analyze the size, structure, and distribution of this isolated island population of gopher tortoises and to determine environmental factors affecting the characteristics of the population.

STUDY AREA

Cape Sable (Figure 1) is the southwestern projection of the Florida peninsula. The general area has been described by Craighead (1971). The cape is isolated from the mainland by Whitewater Bay and by a canal between the Bay and Flamingo. The beach dunes of Cape Sable are further isolated by surrounding mangrove forest. Beaches of marl and shell sand with some quartz sand occur along East, Middle, and Northwest Capes. Middle and East Capes are separated from the rest of Cape Sable by an inland lake and canals. The spatial sequence of vegetation away from the beach is similar on all three capes (Figure 2). Beach front is backed by grassland that gives way to hammock and mangrove swamp forests. The xeric grassland vegetation present over most of the main study site on East and Middle Cape is the primary habitat used by gopher tortoises (Figure 2). This extensive grassland prairie, covering an alternating series of low dunes and swales, is composed of Lantana involucrata, Schizachyrium semiberbe, Andropogon virginicus, Boerhavia repens and clumps of Cocos nucifera, Sabal palmetto, and Agave spp. Inland, on the highest elevations, is a strand of hardwood hammock forest containing well developed trees of Bursera simaruba, Piscidia piscipula, Ficus aurea, and Yucca aloifolia. A few burrows were found in the hammock area on Middle Cape. Beyond the hammock are mangrove swamp forests, dominated by Rhizophora mangle. The grassland of Middle Cape occupies more area than on either Northwest Cape or East Cape. As a result of a larger catchment area the ground water is fresh, with potable water occurring 50 m from the beach, even during periods of extreme drought (Russell 1971).

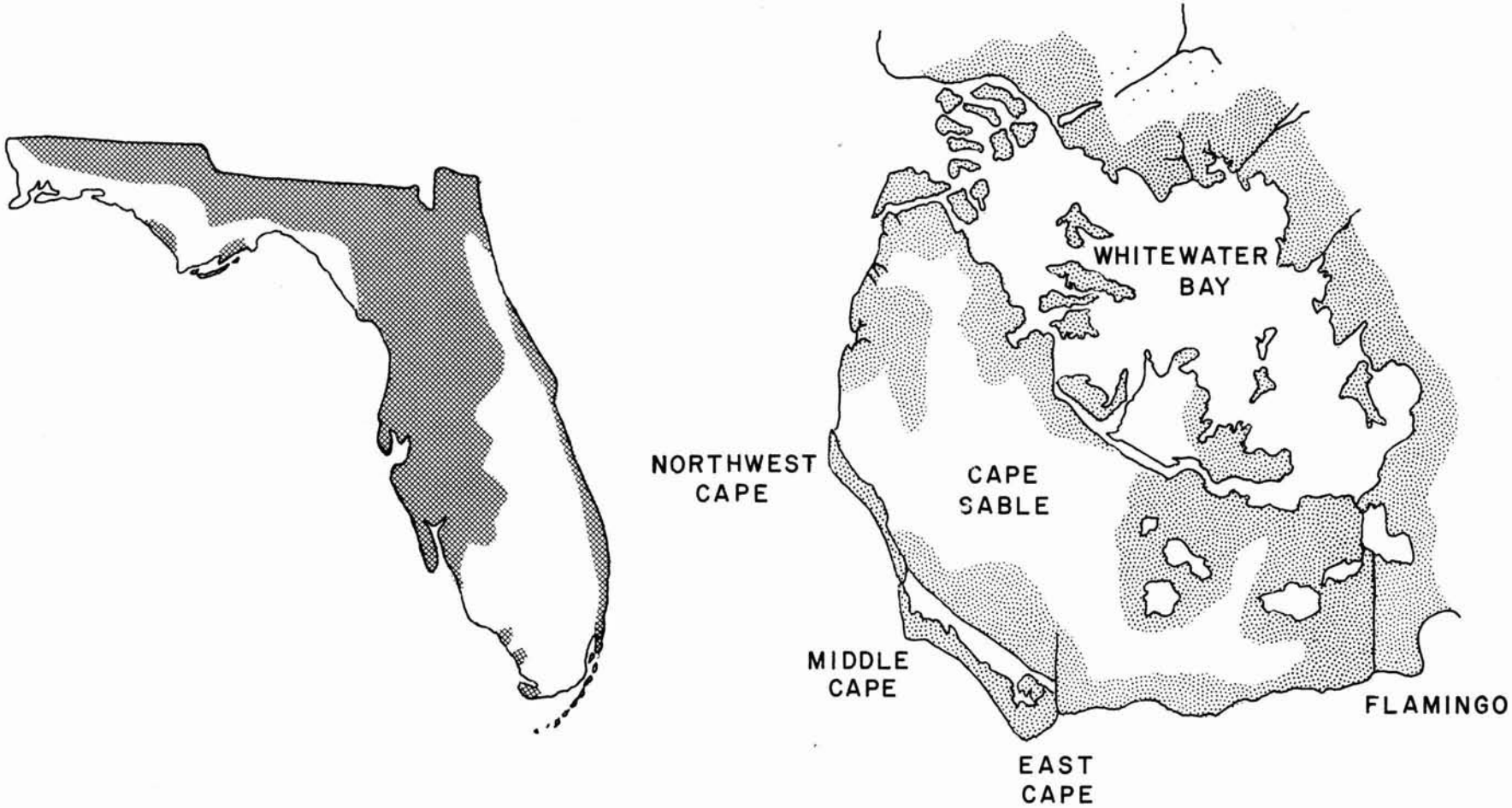
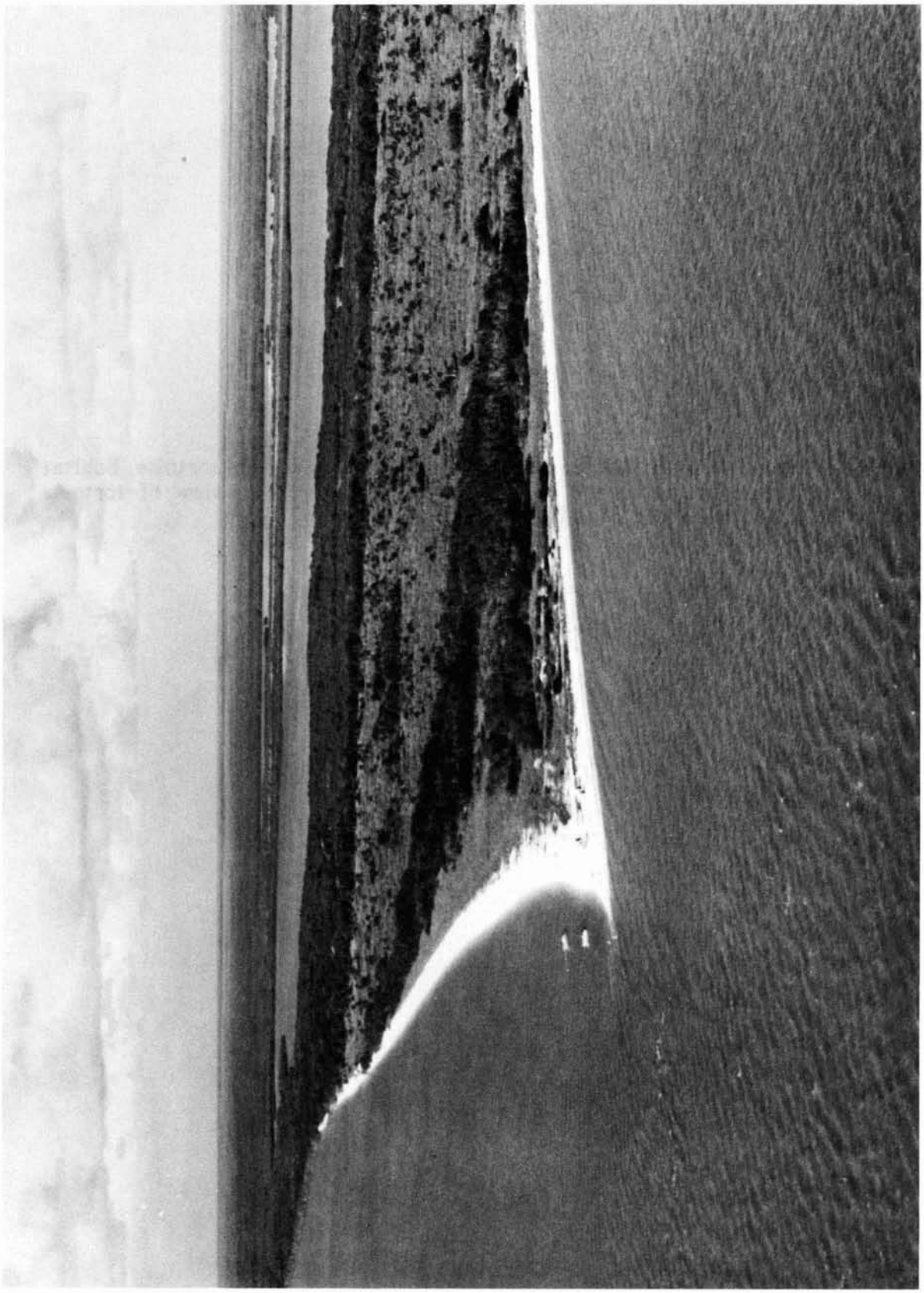


Figure 1. Range of the gopher tortoise in Florida, from Auffenberg (1978), and a map of Cape Sable, at the southwestern tip of the peninsula.

Figure 2. Aerial view of Middle Cape, Cape Sable showing tortoise habitat between the beach and coastal forest (p. 4). Aerial view of tortoise habitat on Middle Cape (p. 5).



METHODS

All suitable habitat of Cape Sable was searched for gopher tortoise burrows, and areas where they were found were censused by transect. The transect censuses were first used on November 14-16, 1978 during a preliminary survey conducted by Todd Logan (pers. comm.). Following methods devised by Auffenberg and Franz (1975), his transects were 7 m wide and 150 m long. A more complete census, conducted on August 22-23, 1979 on Middle Cape and November 18, 1981 on East Cape is the basis for the population estimates in the current paper. Sixty 7 m wide transects were walked from the beach to the tree line and back to the beach. Five persons walked each transect, if it was more than 100 m long, and counted all burrows within the transect. Shorter transects were walked by 2 people. The transects covered 13.8 h, or 12% of the 113.3 h of total area. Following Auffenberg and Franz (1975), burrows were classified as active (signs of recent use), inactive (leaves, twigs in hole, no signs of recent use), or abandoned. The distance of each burrow from shore was recorded. Studies elsewhere have shown that on the average 38.6% of all burrows are unoccupied (Auffenberg and Franz 1975). We therefore applied a correction factor of 0.614 turtles/burrow to the count of active and inactive burrows in order to estimate the number of tortoises in the population. A permanent plot of 1.45 h was established in August 1979, and all burrows were counted, marked, and measured (width x height) at the mouth where the burrow narrows. The plot was recensused on November 8, 1980 and February 22, 1982. In 1982 we also measured as far into the burrow as possible to correspond with the method used by Alford (1980). For conversion of burrow width to carapace length, we used the equation $\log_{10}Y = 0.879 \log_{10}X + 0.149$ (Alford 1980). Dispersion of burrows was analyzed using the nearest neighbor method (Poole 1974).

Data from the plot was also used to evaluate the accuracy of the transect census. Transects run within the plot produced an estimated burrow density of 51.82/h, whereas the plot actually contained 51.03/h. This comparison suggests that the transect data were an adequate estimate of tortoise burrow density over the entire study area.

RESULTS

Extensive survey work showed that gopher tortoises were confined to Middle and East Cape (Figure 1). The census of 60 transects in August 1979 and October 1981 located 253 active and inactive burrows. From this, we estimate the population to be 1275 tortoises at a burrow density of 11.3 tortoise/h.

Burrows were scattered throughout the dune area, from the foredune to slightly beyond the tree line (Figure 3). Three burrows were found within 10 m inland of the beach front, the small number possibly being the result of periodic overwash. Nonetheless, tortoises were active in this area, as evidenced by scat and trails. The dispersion of burrows within the study plot in August 1979 was random

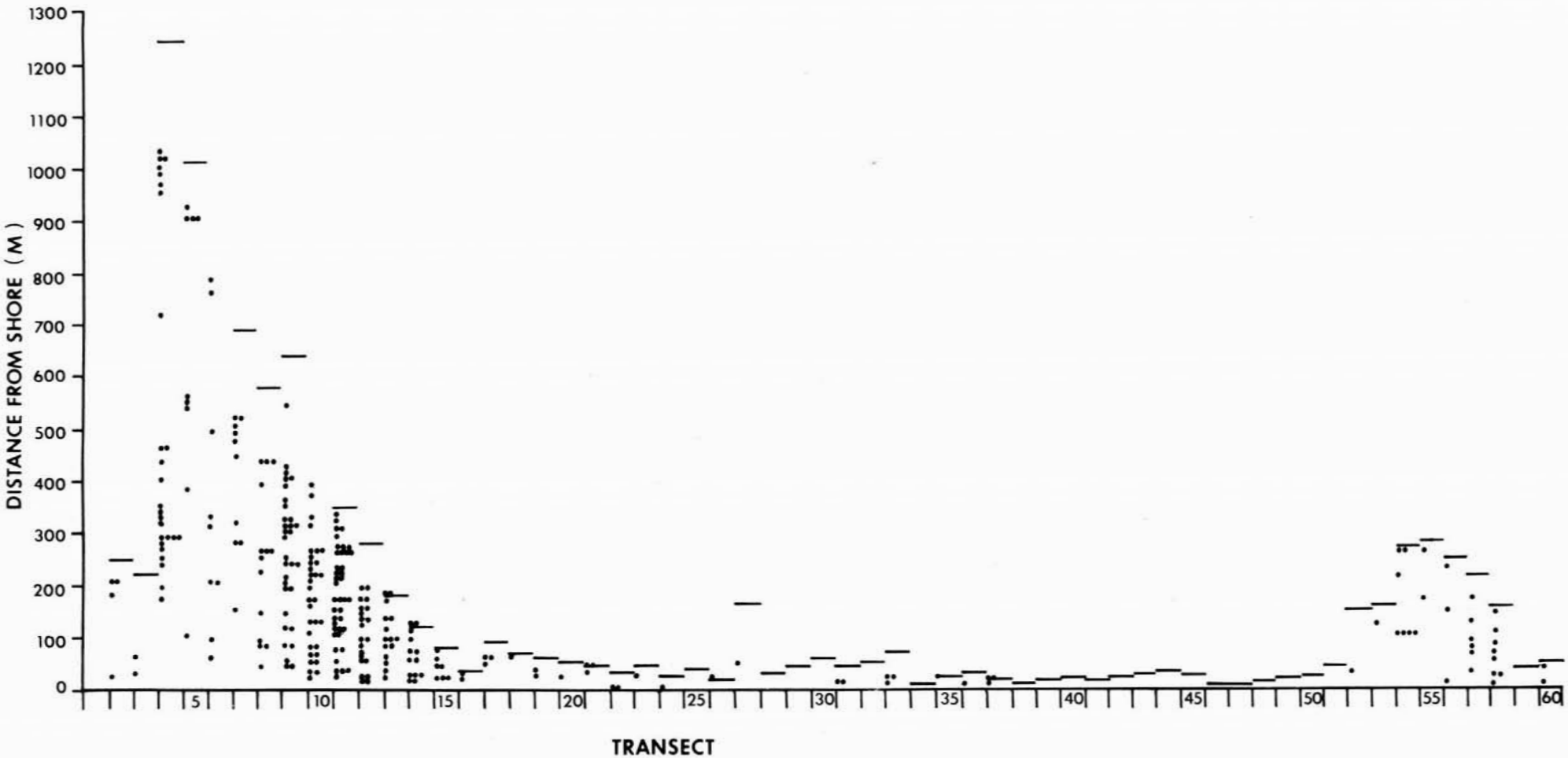


Figure 3. Distribution of gopher tortoise burrows (active, inactive and abandoned) on transects from Middle Cape (transect 1), to East Cape (transect 60). Transects covered coastal prairie vegetation perpendicular to the shore from the beach to coastal forest, indicated by horizontal slashes.

(R = 1.09, Z = 1.5, N = 73), but there appeared to be a concentration of burrows on ridges with fewer in the intervening swales. There was no apparent preferred use of vegetation stands within the prairie; some burrows were located under trees.

The three complete censuses conducted on the study plot provided some information on the trend of population change. In 1979 we found 74 active and inactive burrows; in 1980 we found 84; in 1982 we found 86. Thus, the population on the plot appears to be growing.

Some idea of the relative size structure of the population can be obtained from the measurements of burrow mouths (Table 1). The existence of small burrows, less than 15 cm, suggests that recruitment may be occurring within the population. The smallest burrow was 6.0 cm wide. These were made by young tortoises, although probably not by hatchlings (Alford 1980), which on hatching are about 4 cm wide (Arata 1958). Most burrows were between 25 and 40 cm wide.

Alford (1980) determined the relation between burrow width and carapace length of gopher tortoises. In 1982, we also took burrow width measurements in a way comparable to Alford's and so are able to use his relationship to generate a size-frequency distribution for the population segment in the study site (Figure 4). The resulting distribution shows a predominance of animals in the 25-35 cm carapace length classes, with good representation of smaller animals.

DISCUSSION

The southernmost gopher tortoise population, located on Cape Sable, Florida, appears to be relatively healthy. From our census data, we estimate the population to be in excess of 1200 individuals in 113 h of habitat. This population density can be compared with populations censused in other areas. Logan (pers. comm.) found tortoise populations on 17 Federally-managed areas in Florida had densities ranging from 0.3 to 11.9 tortoises per hectare of habitat. Auffenberg and Iverson (1979) listed densities in various habitats as 0.4-20.6 tortoise/h. Only the highest density was greater than the density on Cape Sable. Thus the population density of 11.3 tortoise/h may be relatively high.

The population seems entirely isolated from other populations and has been since rising sea level isolated it or since it was introduced. Gopher tortoises occurred historically as far as the pinelands further inland in the park. Sporatic observations continue to occur in this area, such as ones in 1955, 1957, 1960, 1979, and 1981. In 1982 individuals were reported also in the Big Cypress Swamp and on Elliott Key in Biscayne Bay. It is likely that these stray individuals were released rather than being remnants of the natural population.

There has been some suggestion that the gopher tortoise population may have been introduced onto the Cape within historic time (McKinney 1970). Tebeau (1968) discussed the history of human occupation of the Cape. It was probably used only

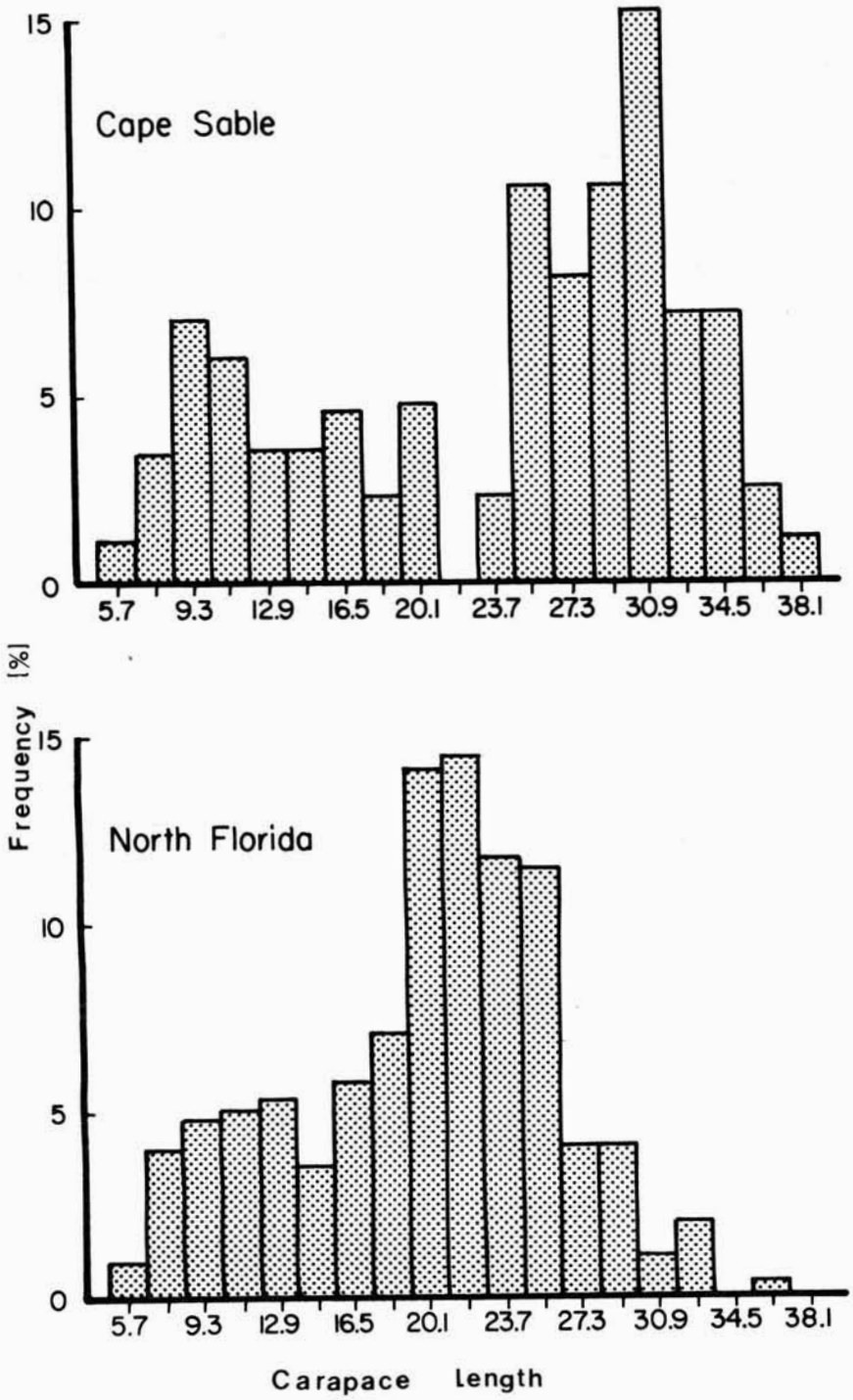


Figure 4. Comparison of the frequency distribution of calculated carapace lengths of the gopher tortoise population on Cape Sable with one in north Florida, from Alford (1980).

Table 1. Distribution of the widths of the mouths of gopher tortoise burrows in a 1.45 h study plot on Middle Cape.

Size Range (cm)	August 1979	January 1982
5-9.9	4	9
10-14.9	7	13
15-19.9	3	3
20-24.9	5	4
25-29.9	11	14
30-34.9	11	26
35-39.9	22	13
40-44.9	6	1
45-49.9	5	3

sporatically by Indians, and the first white occupation of the site was in 1838 during the Seminole War when a fort was constructed at East Cape. Records exist of occasional occupancy and farming activity, including cattle ranching by the turn of the 20th century and the establishment of a coconut plantation that was finally destroyed in the hurricane of 1935. It is possible that some of these occupants of the Cape introduced the tortoises there.

Several lines of evidence support the possibility of introduction. McKinney (1970) excavated 5 burrows and, not finding the commensal species usually associated with gopher tortoise burrows, concluded that the population was probably introduced. In excavating two burrows in 1982, we found them occupied by slugs and a whip scorpion. Although these are not obligate commensals, their presence indicates the burrows are suitable habitats for such animals. Another piece of evidence is that the tortoise does not occur now on Northwest Cape, which is separated from Middle Cape by a canal dug in the early 1920's (Tebeau 1968). If this canal were a barrier to dispersal, introduction after the 1920's is suggested. Also, George R. Fischer (pers. comm.) examined records of material collected from 2 indian midden sites on Cape Sable and found no turtle remains.

None of these pieces of evidence are conclusive. The lack of obligate commensals may be the result of their failure to persist after overwash by storms and hurricanes (Craighead 1971). Little is known about tortoise populations on other coastal islands of Florida and whether obligate commensals are able to persist in those sites. Without such information we should not give too much weight to the absence of specialized commensals. Simpson in a book published in 1920 noted the existence of gopher tortoises on Cape Sable, proving the population did exist prior to the construction of the canal separating Middle from Northwest Cape. The absence of tortoises on Northwest Cape may be the result of its hydrologic regime. During drought conditions the fresh ground water lens leaches from under Northwest Cape permitting salt water intrusion; whereas, Middle Cape retains a lens of freshwater throughout dry periods (Russell 1971). It was probably for this reason that freshwater wells were dug on the Middle Cape for use by ships and that the earliest occupation and attempts at farming were all on Middle Cape (Tebeau 1968). Such periodic restriction of freshwater sources might inhibit the survival of tortoises on Northwest Cape. The lack of tortoise remains in Cape Sable middens may mean that they were not eaten frequently enough to be excavated in a midden collection. Perhaps this was because the population was usually small from cropping or from environmental factors as discussed beyond. Thus, the question of introduction must remain unsettled.

The population was rediscovered on Middle Cape on October 9-10, 1949 by W. Dilley, R. O. Woodbury and J. B. Earle. Subsequently, on March 2, 1950 Moore (1953, pers. comm.) found a number of burrows and signs of activity on East Cape. He later observed them there in February 1951, March 13, 1952, May 15, 1952, and D. Karraker saw burrows on March 9, 1955. In the early 1950's, the population must have been considerably smaller or at least less noticable than at present,

because Dr. Albert Schwartz (pers. comm.) spent several days camping at the caretakers house on the old coconut plantation on Middle Cape. He did not see any tortoise burrows and so was unaware of their existence when he wrote his monograph on south Florida reptiles (Duellman and Schwartz 1958). Tortoises were present on both East and Middle Cape in 1960 and 1961, proving their survival after Hurricane Donna in 1960. On April 2, 1966 after Hurricane Betsy, Ernst T. Christensen censused 81 hectares and found 0.2 burrows/h.

The population was undoubtedly small in the 1950's and 1960's and has increased in recent years. The present population density on Middle Cape is 50 times that of 1966, a substantial increase in 16 years. The population is continuing to grow, as evidenced by the number of burrows on the study plot increasing by 19, or about 7% per year, between August 1979 and January 1982.

The population has a relatively high proportion of larger, presumably older animals, the predominance of animals being 25-35 cm long (calculated carapace length). This population includes larger animals than Alford (1980) found in northern Florida, where most animals were 19 to 27 cm long (Figure 4). Alford interpreted his data as demonstrating a relatively large number of larger tortoises in his population. He stated that a likely explanation of this result was a slowing of the development rate in older tortoises, leading to bunching of older cohorts. It would seem the lack of even older animals in his study might be caused by human exploitation of older animals. On Cape Sable, free from such exploitation, even older age classes are represented. The population size and structure on Cape Sable is probably not determined by natural predation. No animals on the Cape would eat larger turtles. Although raccoons (Procyon lotor), bobcat (Lynx rufous), and crabs probably eat small tortoises, small burrows exist in relatively high numbers (Figure 4).

More likely the population is affected primarily by drought and storms. Seasonal drought may adversely affect tortoises, especially where fresh water does not persist during the dry season. Most tortoises occur on Middle Cape, few on East Cape, and none on Northwest Cape. As noted, this distribution may be determined by groundwater hydrology. Rainfall may also affect tortoises directly. We found burrows in swales filled with water in the summer, and Moore (1953) reported how raccoons use such water-filled holes for drinking. Drowning of burrows would affect details of burrow placement, even if not killing tortoises.

It would seem storms could have a profound effect on population size and distribution. The low populations of the mid-1950's followed hurricanes of late 1940's and early 1950's. Tortoises survived hurricanes in 1960 and 1965, but in relatively small numbers. In 1965, after a storm, Christensen found the tortoises 60 to 150 m from the beachfront. With the greatest number of holes 150 m inland, close to the hammock ridge. This distribution suggests that survival was greatest furthest inland on relatively high and more stable ground. Today a few burrows occur within 10 m of the shore. It is possible that the current population expansion may coincide with the latest inter-hurricane period.

It is possible that storms and drought may also account for the current age structure. Growth rates of gopher tortoises are complex, varying with age, nutrition, and latitude (Landers et al. 1982). Growth rates are higher in more southerly populations, averaging 1.77 cm/yr in the relatively warm climate of north-central Florida (Landers et al. 1982, Auffenberg and Iverson 1979). If Alford's (1980) best estimate of growth rates in Florida of 1.8 cm/yr is similar to that of Cape Sable tortoises, members of the modal size class (Figure 4) would be 15 years old (30.9 cm mid-point - 4.5 mm hatchling size (Auffenberg and Iverson 1979)), this is about the time since the last major hurricane in 1965. The dip in the 22 cm size class (Figure 4) is also of interest. Those animals (approximately 10 years old) would have hatched during the last severe drought of 1971 (Russell 1971). Thus if the growth rates are approximately correct, hydrologic and storm events may determine both the structure and the size of the tortoise population on coastal beaches of Cape Sable, Florida.

Cape Sable is part of Everglades National Park, and the population is thereby protected from the hunting that occurs elsewhere in the state, thus the most severe threat to the tortoise seems to be from hurricanes. The hurricanes of 1935, 1960 and 1965 considerably modified the Cape, eliminating most man-made structures. In fact, the Cape Sable dune system, consisting of dune and swales of successive deposition, was in large part shaped by storms (Craighead 1971). Alford (1980) concluded that long-term habitat stability may be needed for tortoise survival. However, coastal beaches are inherently unstable. On Cape Sable, the tortoise population appears to have survived storms, but in reduced density. If inter-colony movement is low under the best of conditions (Alford 1980), recolonization of isolated population centers such as Cape Sable would be an unlikely event. Thus local extinction of the population on Cape Sable may be an eventual possibility and at any time its numbers and structure are determined by the recent history of environmental conditions.

ACKNOWLEDGEMENTS

We especially thank T. Logan and H. W. Campbell, U.S. Fish and Wildlife Service, for conducting the preliminary census and establishing the transect procedures. We thank those who helped with the field work, suffering the abuses of Agave spears and cactus spines, including B. Brown, D. Brown, S. Christman W. Dunson, R. Franz, P. Frohring, M. Jacobsen, P. Moler, A. Muller, D. Peck, S. Raney, C. R. Smith, and D. Smith. We thank A. Schwartz, W. B. Robertson, Jr., F. Whitehead, W. Dunson, and, especially J. Moore, who discussed their observations and contributed information on the historical status of the population. Various tortoise observations that we cite were made by W. Dilley, R. O. Woodbury, J. B. Earle, J. C. Moore, M. Duesing, D. O. Karraker, R. McDowell, F. C. Craighead, Sr., K. Vernick, and D. Culliard. The census of E. T. Christensen in 1966 was especially important. We also thank others who assisted us in finding information, including P. Meylan, G. Robinson, G. P. Fischer, T. Logan, and W. Dunson. Dottie Anderson and Betty Curl typed the manuscript.

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