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Distribution Of Two Lizards, Cnemidophorus Tigris And C. Scalaris, In Pine Canyon, Big Bend National Park, Texas

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This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of The University of New Mexico in partial fulfillment of the requirements for the degree of Master of Science

DISTRIBUTION OF TWO LIZARDS, CNEMIDOPHORUS TIGRIS AND C. SCALARIS, IN PINE CANYON, BIG BEND NATIONAL PARK, TEXAS

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DISTRIBUTION OF TWO LIZARDS,

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IN PINE CANYON, BIG BEND NATIONAL PARK, TEXAS

By

Ronald V. Lucchino

B.A., Mansfield State College, 1965

THESIS

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ABSTRACT OF THESIS

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ABSTRACT

At the lower elevations, 3500 ft or less, in Pine Canyon, *Cnemidophorus tigris* and *C. scalaris* occupy the same general areas. Corresponding with a rise in elevation, the increase in vegetation density forces both lizards from the flat terrain into the arroyos that drain the canyon. Of the two species, only *C. scalaris* is found above an elevation of 4000 ft. At this elevation the coarseness of soil texture in the arroyos becomes evident and the sides of the arroyos are steeper. These changes are the result of the increase in the slope of the canyon.

Air and soil temperatures appear to offer no physical barriers to the elevation that can be attained by *C. tigris*.

This species is a fast and nervous forager that may require flat and sparsely vegetated areas not found at higher elevations in Pine Canyon. At one time *C. tigris* may have inhabited higher elevations because, according to Taylor, McDougall, and Davis (unpublished), drought and overgrazing during the 1940's left this area sparsely vegetated. As the area recovered, *C. tigris* and *C. scalaris* may have been forced to move down the canyon, with *C. tigris* moving faster because the increase in vegetation limited the area needed for foraging, whereas *C. scalaris* moved more slowly because it can cope with more dense vegetation.

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INTRODUCTION

In 1958, Degenhardt, while making an ecological survey in Big Bend National Park, noticed that two subspecies of *Cnemidophorus*, *C. tigris marmoratus* and *C. scalaris septemvittalus*, occupied adjacent and sometimes overlapping habitats. I have found *C. tigris* occupying a flat and sparsely vegetated area, while *C. scalaris* inhabits the arroyos in the same vicinity and on occasion has been seen with *C. tigris* on the flats with no observable interspecific competition. Also Milstead (1961) observed, near Black Gap Wildlife Management Area just east of the park, no competition between the two species. The interesting aspect is that in a given area *C. tigris* is not found above a certain elevation, but *C. scalaris* was observed occupying the same habitat as occupied by *C. tigris* at lower elevations.

In the present study I attempted to determine why *C. tigris* is restricted to lower elevations. I considered the possibility of the distribution pattern being the result of an ecological barrier, of behavior patterns, or of physiological factors. To answer these questions, a canyon had to be located that offered a sufficient increase in elevation to exhibit this elevation restriction. The canyon selected was Pine Canyon (Wade Canyon), one of the major drainages of the Chisos Mountains in Big Bend National Park, Brewster County, Texas. In this canyon an ecological study was initiated in order to examine possible factors affecting the distribution of *C. tigris*.

LITERATURE REVIEW

Species Descriptions

The family Teiidae is comprised of 35 genera. Only one genus, Cnemidophorus, is found in the United States (Bostic, 1966). This genus is usually divided into three species groups: sexlineatus, tesselatus, and hyperythrus. Two of the groups, sexlineatus and tesselatus, are represented in this study. The tesselatus groups contains the subspecies C. tigris marmoratus while the sexlineatus group contains the subspecies C. scalaris septemvittatus (Milstead, 1957a, p. 427). The species name C. scalaris has priority over C. septemvittatus, the species name previously used (Williams and Smith, 1963).

The average snout-vent length of adult C. scalaris is 66 mm for females and 70.7 mm for males (Milstead, 1961). The new born have an average snout-vent length of about 37 mm, while the juvenile's snout-vent length averages 44 mm (Minton, 1958). The adult form of C. tigris has approximately the same snout-vent length as the length of the adult C. scalaris. Data is not available for juvenile C. tigris.

A young C. scalaris has distinct black and white longitudinal body stripes and a blue tail, superfically resembling adult C. inoratus. The adult C. scalaris has small white lateral bars on the black stripes. Also, the hind legs and blue tail of the young C. scalaris turn brown as it approaches adult size (Figure 4a).

The body of the adult C. tigris has a marbled appearance that distinguishes it from the more markedly striped C. scalaris. The sides of C. tigris have alternating dark and light longitudinal bars. There is also a slight indication of dorsal striping (Figure 4b). The throat coloration is white, pink, or orange, with black spots (Stebbins, 1966, p. 133).

Milstead (1961) found, by examining stomach contents, that both C. scalaris and C. tigris have about the same food preferences. Termites of the genus Amiterne appear to be the favorite, orthopterans rank second, followed by a small percentage of coleopterans, lepidopterans, and hemipterans.

McCoy and Hoddenbach (1966) observed that the number of clutches produced by C. tigris in Texas was two per year, with an average of 2.2 eggs per clutch. The eggs are layed between April and mid-August. Milstead (1957a) observed the same number of clutches per year for C. scalaris, but made no mention of the number of eggs per clutch.

Behavior

Other than color and pattern the most noticeable difference between C. tigris and C. scalaris is their method of foraging. Cnemidophorus tigris is a rapid forager and exhibits erratic and nervous movements, whereas C. scalaris is a slower, more smooth, and more methodical forager (Milstead, 1957b, p. 109). Due to this difference in behavior, the amount of terrain C. tigris can cover in 0.5 hr is 150 yards; however, in the same period of time C. scalaris can cover only 100 yards (Milstead, 1957b).

Milstead (1957a), at the Black Gap Wildlife Management Area, observed that home range of both species is similar, with a maximum of 0.43 acres for C. scalaris and 0.53 acres for C. tigris. The size of the home range is inversely proportional to the vegetative density and directly proportional to the amount of food, and amount of local rainfall. When the flora density is low, the home range is usually larger, but if the flora density is high, the home range is usually smaller.

Milstead (1957a), in citing Crombie, defined two forms of competition. The first form of competition is intraspecific, wherein one species inhibits its own potential increase more than it does that of other species and both continue to exist together. The other form of competition is interspecific, wherein one species directly or indirectly inhibits the other species more than it does itself. Direct competition occurs when two or more organisms simultaneously make demands on the same environment in excess of necessary commodities, whereas indirect competition is the interference of one species by another even when there are no demands for common resources of space or food. Direct competition can be either (i) active, with social intolerance between individuals or groups of individuals over mates, territory, or any desired commodity, or (ii) passive, with competitive behavior not closely aligned to social behavior and is more concerned with the population as a whole more than with and individual in the population.

As an illustration, one species can consume a food supply in an area and thus make food unavailable for other species which, even though present, do not actively compete for food (Milstead, 1957a, p. 442). Passive competition is the only type exhibited by indirect competition. If two or more species of whiptails exist in an area and each exhibits passively competition, only one is destined to survive due to one of three factors: (i) all interspecific competition will be eliminated through an advantage not visible; (ii) in the absence of an advantage, initially higher numbers will eliminate other species; (iii) if equal in all factors, probability will eliminate all but one species (Milstead, 1957a, p. 443).

Habitat

The terrain occupied by *C. tigris* is generally flat and is characterized by a fine soil texture and a low flora density (Degenhardt, 1966, p. 88). *Cnemidophorus scalaris*, unlike *C. tigris*, can forage in a higher flora density and a coarser soil texture. Milstead (1957a) found that the two species of *Cnemidophorus* do not appear to have any preference for certain plant species.

The elevational range of *C. tigris* in the park varies from 1800 ft in the lowlands to approximately 4500 ft on the north slopes and possibly higher on the south slopes of the Chisos Mountains. *Cnemidophorus scalaris* is found with *C. tigris* at 3000 ft, but above 4500 ft only *C. scalaris* has been observed in Green Gulch (Degenhardt, 1966, p. 67).

DESCRIPTION OF THE AREA

Big Bend National Park

Big Bend National Park is found in the southernmost portion of the area called Big Bend, which is commonly considered to lie south of the Southern Pacific Railroad in Presidio and Brewster counties in Trans-Pecos Texas. The Big Bend area recieved it name from the U-shaped bend of the Rio Grande, which separates Texas from Mexico and borders the area on the west, east, and south. The area is part of the Chihuahuan biotic province which is characterized by low rainfall and sparse vegetation. The Park encompasses approximately 700,000 acres.

The elevation of the park ranges from 1800 ft at the river to 7835 ft on the top of Emory Peak in the Chisos Mountains. The mountains bordering the eastern section of the park are part of a mountain system which in the United States is called the Sierra del Caballo Muerto and in the state of Coahuila, Mexico, the Sierra del Carmen. The Sierra del Caballo Muerto has a maximum elevation of approximately 5800 ft. Mesa de Anguila, bordering the park on the west, has an elevation of 3900 ft. The northern sections of the park are bordered by various distinct mountain peaks. The Chisos Mountains dominate the center of the park (Figure 1). The Chisos result from an igneous uplift during the Tertiary period (Maxwell, 1968). As the bajadas surrounding the Chisos are covered by the outwash from the mountains, there is a gradation of soil texture from coarse to fine with decrease in elevation.

The vegetation of the Chisos Mountains varies with elevation with such trees as Douglas-fir and ponderosa pine growing at the higher elevations. As the elevation decreases there is a gradual change from oak-pinon community to sotol-beargrass community, and at the lower elevations creosote and mesquite occur.

The main canyons, which form the drainage for the Chisos, are Green Gulch (containing the only paved road into the mountains), Oak Canyon, Blue Creek Canyon, Cattail Canyon, Juniper Canyon, and Pine Canyon (writer's study area).

The temperature of the area varies with elevation. In the lowlands (1800 ft) the daily temperature may reach 120 F, with an average of 100 F. These extreme temperatures usually occur in June, July, and August. In the mountains (5500 ft) the average diurnal temperature during the summer is approximately 85 F.

Rainfall, like temperature, varies according to elevation. At the lower elevations the average is less than 10 inches per year and is unevenly distributed so that some areas may recieve no rain at all during a given year. In the mountains rainfall averages 20 or more inches per year. Because temperature and rainfall are recorded in only certain sections of the park, there is a lack of accurate meteorological data in vast areas of Big Bend. Among areas lacking data is Pine Canyon, and this forced the writer to take measurements of certain meteorological conditions in the study area.

Pine Canyon

Pine Canyon was chosen as the study site because of the desirable rise in elevation in the canyon.

The canyon, which cuts throught the eastern slope of the Chisos Mountains, is 5 miles in length from the mouth to the waterfall which marks the head of the lower canyon. The first 4 miles of the canyon has a dirt road, while the last mile has only a foot path. This last mile of the canyon is very narrow and is characterized by a heavy tree canopy. The study area encompassed only the first 4 miles.

The dirt road in the canyon was used as the dividing line to separate the canyon into north and south sections. Both areas were examined and found to be similar in terrain, type and density of flora, and habitat of lizards. The section chosen for the survey was the south section. No favorable or unfavorable factors affected this decision as both areas were seemingly equal in all significant aspects.

The canyon's width varies from a minimum of 0.5 miles to a maximum of 1.75 miles. The rise in elevation from the mouth (3500 ft) to the end of the road (5000 ft) is about 1500 ft, or approximately 400 ft per mile. The first mile has a grade of 300 ft per mile, the second has the steepest grade, 500 ft, the third has a grade of 300 ft, and the last mile, 400 ft. The lower elevations are characterized by the type and density of flora common to the Chihuahuan desert, while the higher elevations exhibit the density and type of flora expected in areas of increased rainfall.

The variations in density and flora type can be seen in Figure 2.

The sides of the canyon are composed of igneous material, resulting in a soil texture that varies between sand and large pieces of granite, depending on the elevation. The south wall consists of an eastern section and a western section. The eastern part of the wall, Hayes Ridge, is a igneous dike 2 miles long and rises to 4500 ft. The western part of the wall, Crown Mountain, is 2 miles long and has a maximum elevation of 7000 ft. The north wall is also comprised of eastern and western sections with a low area separating them. The eastern part of the north wall is a small igneous plug approximately 1 mile long. This plug is called Nugent Mountain and has an elevation of 4700 ft. The western portion of the wall is part of Pummel Peak (6500 ft), which is a part of the north face of the Chisos Mountains. The low area between the two walls has an elevation of only 4200 ft and a length of 1 mile. The numbers in Figure 1 correspond to the location and number of the stake that identifies the sector and the x marks indicate the positions of the three weather stations.

Arroyos

The system of arroyos shown in Figure 1 can be traced from 3500 ft as one arroyo of considerable size which divides into two at 3800 ft. One drains to the north of the road and the other drains the areas south of the road. The southern arroyo divides at 4000 ft, resulting in a drainage of the middle and extreme southern parts of the canyon. The arroyo depth (3 ft to 15 ft) and width (2 ft to 20 ft) is directly related to the elevation within the canyon. The type of soil texture found on the arroyo floor also depends on the elevation, with more coarse texture found at higher elevations. Figure 3 shows arroyos at various elevations.

METHODS AND MATERIALS

A preliminary study of the area made it evident that July was the optimum time to begin the actual survey. August was eliminated because it is the beginning of the rainy season and it is the time of year adult activity starts to decrease. June was needed to choose and become familiar with an appropriate study area.

Several survey procedures were tried to determine the most feasible in the study area. An east-west line transect at various intervals was not deemed useful because such a transect, in being placed randomly, might not show the exact elevation to which C. tigris is restricted and important flora zones of transition might be missed. A north-south transect along the canyon was not utilized because important arroyo areas that may affect C. tigris distribution might not be included in such a transect. The only feasible procedure that would include all areas was to survey as much terrain as possible for 1 hr each day.

The sampling was conducted in the morning, starting the first day at the lowest elevation and on the last day ending at the highest elevation. The hour was divided equally so that half of the time was used in walking up the arroyo and half in walking, out of the arroyo, back to the starting point for that day.

In utilizing this method, I divided the canyon into 10 sections, each section having an area equal to the amount of terrain covered in the 0.5-hr walk up the canyon. A stake was driven in the ground near the road where the first half of the hour walk ended each day. Each stake had a number corresponding to a number on the map in Figure 1. The stake marked the end of one sector and the beginning of the next. The total area covered each day was not exactly the same due to the difference in terrain resulting in 10 sections or sectors of unequal length. The length was measured in road miles from the beginning stake to the end of each sector.

When walking the sectors, I observed any lizards and noted the locality, sector, type of lizard, elevation of sector, type of flora, soil and air temperatures, and soil texture. One transect per sector, at the beginning and ending stakes, was used to measure the flora density. By using these two areas, I determined any change in the density between the lower and upper ends of the sector. A 100-ft tape measure was used twice per stake to obtain a density measure for 200 ft. The end of the tape was fastened to the stake and stretched its full length along the ground perpendicular to the road. The tape was placed perpindicular to insure that, if necessary, roughly comparable results could be obtained to form a reference for comparison for future measurements and to note any changes in flora density that might occur with time. In measuring the amount of cover, all plants touching or overhanging the tape were measured and identified. The results from each sector are summarized in Table 1.

No previous meteorological records were reported for Pine Canyon; therefore, in order to examine all possible factors affecting habitat of C. tigris and C. scalaris in the canyon, meteorological information for the lower and higher elevations had to be recorded by the writer. Another reason for recording this information was to establish a reference for future meteorological comparisons.

Three stations were established at determined elevations for recording temperature, precipitation, ground temperature, and soil moisture. The first station was at an elevation of 3600 ft in order to record data for the elevations between 3500 ft and 3800 ft. The second station, located at an elevation of 4100 ft, recorded readings for the sectors between 3800 ft and 4500 ft. The last station, located at an elevation of 4800 ft, established records for the area between 4500 ft and 5000 ft. The stations are indicated by x marks in Figure 1. Maximum and minimum thermometers were placed in wooden boxes which were closed on five sides, with 2 one-half inch holes drilled on each side for proper ventilation. Brackets fastened the thermometers to the back of the box, thus keeping the thermometers from touching the sides which were warmed due to heat absorbed by the box. The boxes were elevated off the ground and placed in the shade to avoid excessive heating by direct sunlight. The elevation of the boxes reduced the possibility of a false air temperature reading resulting from heat radiation from the ground. A thermometer, placed just below the soil surface, was used to record ground surface temperatures at the three stations. These readings were used to assist in determining any variation in the surface temperature at differing elevations. These recorded values (Table 5) were measured once a day at the three stations at approximately the same time between the hours of 9:00 AM and 12:00 PM. The values in Table 5 were obtained by measuring the soil temperature on the arroyo floor at definite increments of elevation. Soil temperatures were taken by a Tri R electronic thermometer or by one of the implanted thermometers where available.

The amount of rainfall was recorded by a rain gauge placed in an open area so that vegetation would not interfere with the amount of rain collected.

Data were collected from these stations for 15 days between the hours of 9:00 AM and 12:00 PM at 24-hr intervals. While recording the data at the stations, a Peerless moisture indicator was placed 0.5 inches under the soil to obtain a record of the moisture content of the soil at certain elevations. The inability of the instrument to give reproducible results at any one time resulted in comparative readings instead of absolute values. The results of the data recorded at the three stations are summarized in Table 2.

When a lizard was observed, the ground and air temperatures of the immediate vicinity were measured with the Tri R electronic thermometer. The measurements were used to determine if there was any correlation between the number of lizards at varying temperatures and at different elevations (Figure 6, 7).

RESULTS

Cnemidophorus tigris and *C. scalaris* were both observed on the flat areas and in the arroyos at elevations of 3500 ft and below. However, with an increase in elevation the distribution of both species appears to become restricted to the arroyos. *Cnemidophorus tigris*, at an elevation above 3900 ft, is no longer observed either in the arroyos or on the flats (Table 4). Corresponding to this change in lizard distribution with elevation increase, there are increases in flora density and soil moisture (Table 1 and Table 2). The amount of rainfall recorded daily at the three stations for July is not indicative of the usual rainfall in Pine Canyon because the 20 days allowed for the collection of rainwater was not sufficient and the month of July was atypically dry.

The amount of rainfall, 20 inches per year at higher elevations in the Chisos Mountains (as compared with 10 inches or less at lower elevations), results in an increase in available moisture at higher elevations. This increase in soil moisture with elevation results in an increase in the flora density. In turn, this increase in density can increase the soil surface moisture by providing a vegetative canopy which reduces some water loss through evaporation caused by the sun heating exposed ground.

As the flora density increases upward from sector 2, there is a corresponding change in the distribution of the two species of whiptails when compared with their distribution at lower elevations (Table 4). Corresponding with this change in flora density and lizard distribution is a change in the arroyos. They become narrower and the texture of the soil on the arroyo floor becomes coarser, with more angular-shaped particles. At 4100 ft this change becomes significantly noticeable (Figure 3).

It was difficult to obtain precise soil temperatures because of the variation in soil texture and the uneven distribution of vegetation at the various elevations. This resulted in a range of values (Table 5). The soil temperatures in Table 5 were recorded, using a Tri R electronic thermometer and a buried thermometer, at the three stations and on the arroyo bottom at varying elevations. Temperature readings were obtained between 9:00 AM and 12:00 PM for 20 consecutive days. The low value recorded in Table 5 for 3700 ft was due to low soil temperature readings the morning after a thunderstorm.

Air and soil temperatures were recorded together at varying times in the morning each day of the study. They appear in Table 8. Soil and air temperatures progressively rise from 8:00 AM to 12:00 PM, but the rise in air temperature is at a much slower rate and never attains the same values as those of soil temperature (Figure 6).

Plotting the number of lizards observed against time, a correlation of time, temperature, and numbers of lizards can be obtained as is shown in Figure 6 and Figure 7. The greatest numbers of C. tigris were observed during the hours of 9:30 AM and 10:30 AM when the ground temperature was between 35 C and 43 C. The maximum number of C. tigris was observed at 10:00 AM when the ground temperature was 39 C. There was a marked decline in the number of C. tigris observed when the ground temperature reached 44 C. At ground temperatures above 49 C no C. tigris were recorded (Figure 7).

Cnemidophorus scalaris was observed between 9:00 AM and 1:00 PM, with a recorded soil temperature ranging between 34.6 C and 53 C. The maximum number of C. scalaris were observed at 10:15 AM when the recorded ground temperature was 40 C (Figure 7). Cnemidophorus scalaris, unlike C. tigris, do not exhibit a marked decrease in numbers as the soil temperature increases until 40 C is reached, when the numbers of C. scalaris then begin to decrease.

When the ground temperature reaches 44 C both species of lizards may be found in the shade of bushes and, if disturbed, will run from one shaded area to another or enter their burrows, but they will not stop on the hot soil.

The air temperatures, summarized in Table 6, were recorded between 9:00 AM and 12:00 PM at various elevations.

DISCUSSION

At lower elevations the soil moisture recorded is not considered to be critically less than that at the higher elevations where C. tigris is not found (Table 2). Thus soil moisture does not appear to be a restricting factor affecting the distribution of C. tigris.

In comparing Table 3 with Table 4, no major flora species appears to discontinue its distribution coincident with the absence of C. tigris at 4000 ft. Therefore, the type of vegetation in the canyon does not appear to have any limiting effect in restricting C. tigris to less than 4000 ft.

Cnemidophorus tigris is found at an elevation of 3600 ft with recorded soil temperatures of 37 C, but at elevations of 4100 ft no C. tigris was observed although 37 C soil temperatures were recorded. There does not appear to be a correlation between soil temperatures and the restriction of C. tigris to lower elevations (Table 4 and Table 5). Soil temperatures appear only to regulate the length of the lizards' activity period and not the elevation at which they live.

Cnemidophorus tigris were observed at an elevation of 3700 ft with recorded air temperatures of 30 C, but at an elevation of 4500 ft, where air temperatures of 30 C were also recorded, there were no observed C. tigris (Table 4 and Table 5). The distribution of C. tigris therefore does not appear to be affected by air temperatures either.

One of the noticeable changes with increase in elevation in the canyon is the increase in vegetative density. Two other important changes with the rise in elevation are the movement of *C. tigris* and *C. scalaris* from the flat terrain to the arroyos and the changes that occur in these arroyos. *Cnemidophorus tigris*, because of the amount of area covered during foraging, must occupy a terrain that has a low flora coverage. I suggest that when the vegetative density becomes sufficiently marked, the efficiency of the lizards in foraging is impaired, resulting in either the movement of the lizard out of the area or the movement into a less dense portion of the same area. Dense grass cover usually results in forcing the lizards into the arroyos. Table 1 shows that at the elevation at which the lizards are forced into the arroyos the grass density increases over that of any other type of flora and that it continues to dominate except at the highest elevations where the combination of grasses and shrubs effectively cover the ground completely.

In measuring the flora density all vegetation that touched or overhung the tape was measured. Table 1 shows that on many sectors the ground flora consists for the most part of grass. At sector 1 the high density count was due to the canopy more than to the cover, but in sector 4 the coverage by the canopy was reduced and the actual density was due to grasses. Not only do grasses reduce the efficiency of the lizards in their ability to forage, but the canopy can reduce the amount of sunlight heating the soil. One way the lizards warm themselves to an optimum foraging temperature is by absorbing the heat from the warm soil. The degree to which either foraging or warming affects the lizards depends on which factor, flora canopy or coverage, predominates. At sector 1 the shading of the soil is the predominant factor, but at sector 4 the ability to forage is hindered, not by the shading, but by the amount of grass that covers the area. Either of these factors can force the lizards off the flats into the arroyos if either is sufficiently pronounced.

The flora density also forces C. scalaris into the arroyos at lower elevations, but unlike C. tigris it is not restricted to elevations of 4000 ft and below. In the arroyo the flora density has no effect in restricting C. tigris to the lower elevations because the amount of vegetation found in the arroyos is sparse in comparison to that on the flats (compare Figure 2 and Figure 3).

Some factor or factors in the arroyo restrict C. tigris to the lower elevations, but appear to have no effect on C. scalaris until 4800 ft, where C. scalaris is then forced out of the arroyo and onto the road (Table 4). Cnemidophorus tigris is also found on the road but not above 3900 ft. A possible explanation of why C. tigris does not use the road to attain higher elevations might be that the canyon increases in width and flatness at 4000 ft. Because this results in the road being less of a grade, runoff water will flow down the road at a reduced speed, resulting in little erosion along the sides of the road. Due to the decrease in erosion, the flora density along the road is greater than the density along a steeper graded road, found below 4000 ft, where the erosion has resulted in less vegetative coverage. Cnemidophorus tigris, therefore, could not obtain food by foraging off the road above 3900 ft. Cnemidophorus scalaris, being able to forage in a more dense coverage than C. tigris, is found on the road above 4000 ft. Here it can obtain food by foraging a short distance off the road where the flora density is not sufficiently great to act as a barrier to C. scalaris as it does to C. tigris.

In addition to foraging being affected by vegetative density, both species are forced off the flats because with the increase in vegetation the amount of sunlight that reaches the ground is not sufficient to heat the soil to the minimum needed by the lizards to warm themselves. This fact will not, however, restrict C. tigris to 4000 ft or below because the lizards can utilize the arroyos to reach higher elevations. Thus the limiting factors restricting C. tigris to elevations of 4000 ft or below must be found in the arroyos.

The higher elevations have deep and narrow arroyos with a coarser soil texture ranging from large angular particles to large rocks in comparison to the flat, smooth, and smaller textured particles in the arroyo at lower elevations. The soil texture and narrowness of the canyon could be limiting factors for C. tigris at 4000 ft and for C. scalaris at 4800 ft. The soil texture might be too angular and the particles too large thereby inhibiting the effective movement of C. tigris when foraging for food. Also, the narrowness of the arroyos does not afford much space for C. tigris to forage. This same reasoning may be true for C. scalaris at the higher elevations because this species may be forced out of the arroyo by the texture of the particles, which are more angular and larger than particles at elevations lower than 4800 ft.

Degenhardt (unpublished), at the Green Gulch (4200 ft) quadrat located on the north slope of the Chisos Mountains, recorded the number of C. tigris observed in different years. In 1957, 42 adults were observed and in 1958 and 1969 the number of adults recorded were 33 and 0, respectively. The most noticeable difference in habitat between 1957 and 1958 and between 1968 and 1969 was in vegetative density. In 1957 the vegetative coverage was 23%, in 1958, 28%, and in 1969, 73%. During the same years other quadrats were operated in Green Gulch. At one (5250 ft), no C. tigris was observed in the quadrat, but C. scalaris was observed. Seven C. scalaris were observed in 1957, nine in 1958, and only one in 1969. The vegetative density of the 5250 ft quadrat was 36% in 1957, 34% in 1958, and 91% in 1969. The increase in vegetative density in Green Gulch at the 4200 ft quadrat seemed to cause a reduction in the numbers of C. tigris between 1958 and 1969. Between the same years, C. scalaris at the 5250 ft quadrat was also reduced in number. Lack of previous records in Pine Canyon made it necessary to use

Degenhardt's survey to make an inference that *C. tigris* might have been observed at a higher elevation in Pine Canyon, even up to 4400 ft, if the vegetative density was at one time similar to the 3500 ft in Pine Canyon. If this were true, then *C. tigris* and *C. scalaris* might not have been forced into the arroyos where it appears there is a limiting factor as to height in elevation that these species can go. Taylor, McDougall, and Davis (unpublished) recommended in their preliminary survey of Pine Canyon that no tourists be permitted in the canyon and that the existing road be used only as a fire road. The reason for this recommendation was that heavy overgrazing in the area has resulted in a very low flora density. This being the case, then *C. tigris* and *C. scalaris* may have been found on the flat areas at higher elevations, and as the area recovered and the flora density increased, the species were forced into the arroyos. Because of the rought texture of the soil in the arroyos at higher elevations, *C. tigris* was forced to move down the arroyos to elevations suitable to its foraging habits. As the area continues to change, *C. tigris* and *C. scalaris* may be forced to an even lower elevation.

CONCLUSION

The behavioral patterns of the two species may be considered as a form of passive competition, which was defined as an elimination of all interspecific competition through an advantage not visible. *Cnemidophorus tigris*, being a fast, nervous forager, needs more foraging space than does *C. scalaris*. The type of soil texture, arroyo width, and flora density can affect the efficiency with which *C. tigris* forages, but has a less pronounced effect on *C. scalaris* which is able to forage under conditions unsuited to *C. tigris*. This ability gives *C. scalaris* an advantage that allows its occurrence at higher elevations than *C. tigris*.

The second part of the definition of passive competition is that in the absence of an advantage, the species with higher initial numbers will eliminate the other through weight of these numbers. In the lower elevations of Pine Canyon, where *C. scalaris* does not have the advantage as it does at higher elevations, it is usually found in the arroyos and the ratio of *C. scalaris* to *C. tigris* at these low elevations is small. *Cnemidophorus tigris* may be competing passively with *C. scalaris* in not having an advantage other than more individuals. This forces the noncompeting *C. scalaris* into the arroyos to obtain food that the more numerous *C. tigris* are consuming on the flats.

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FIGURES

FIGURE 1. Map of the Chisos Mountains showing location of Pine Canyon.

FIGURE 2. Sectors at various elevations in Pine Canyon.

FIGURE 2a. 3500 ft.

FIGURE 2b. 3600 ft.

FIGURE 2c. 3700 ft.

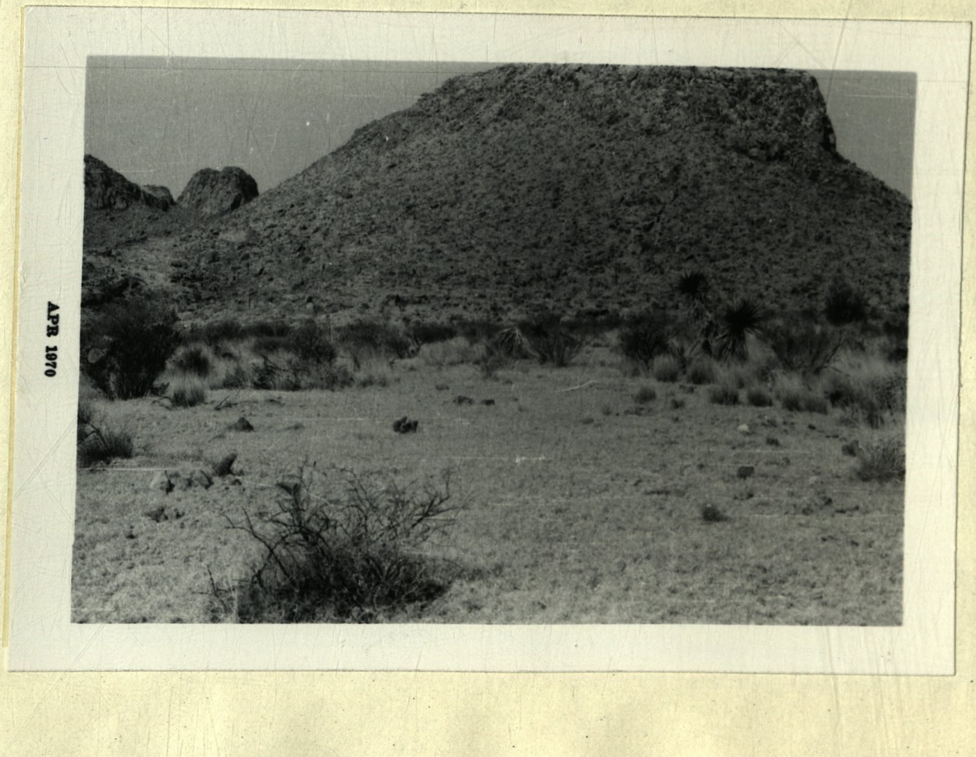

FIGURE 2d. 3800 ft.

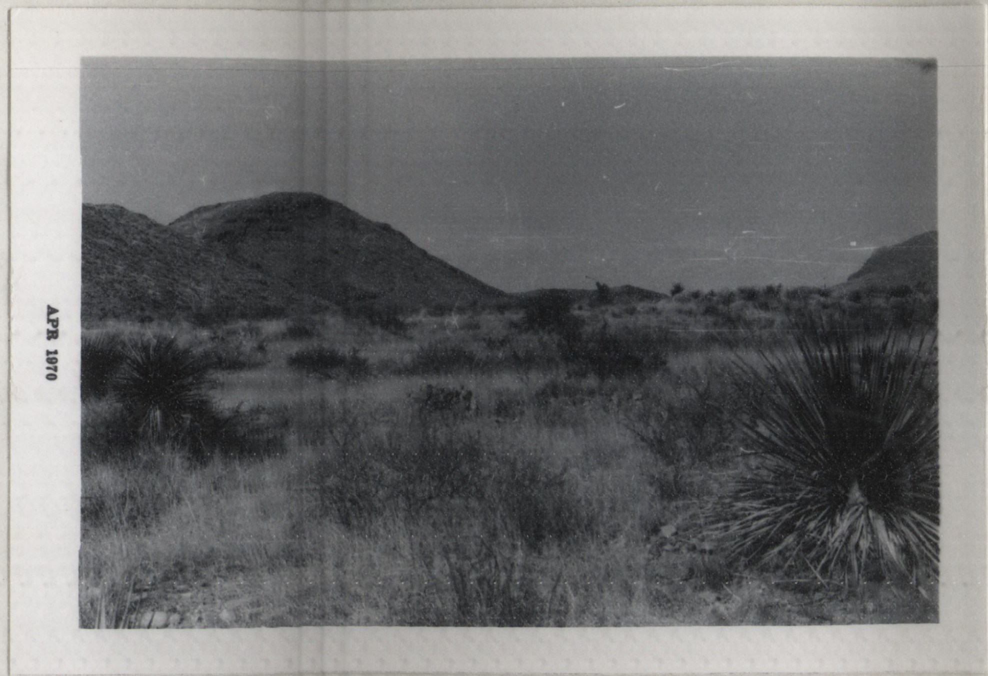

FIGURE 2e. 4100 ft.

FIGURE 2f. 5000 ft.

FIGURE 3. Arroyos at various elevations in Pine Canyon.

FIGURE 3a. 3600 ft.

FIGURE 3b. 3800 ft

FIGURE 3c. 4400 ft.

FIGURE 3d. 4600 ft.

FIGURE 4. Two species of lizards, C. *tigris* and C. *scalaris*, studied in Pine Canyon.

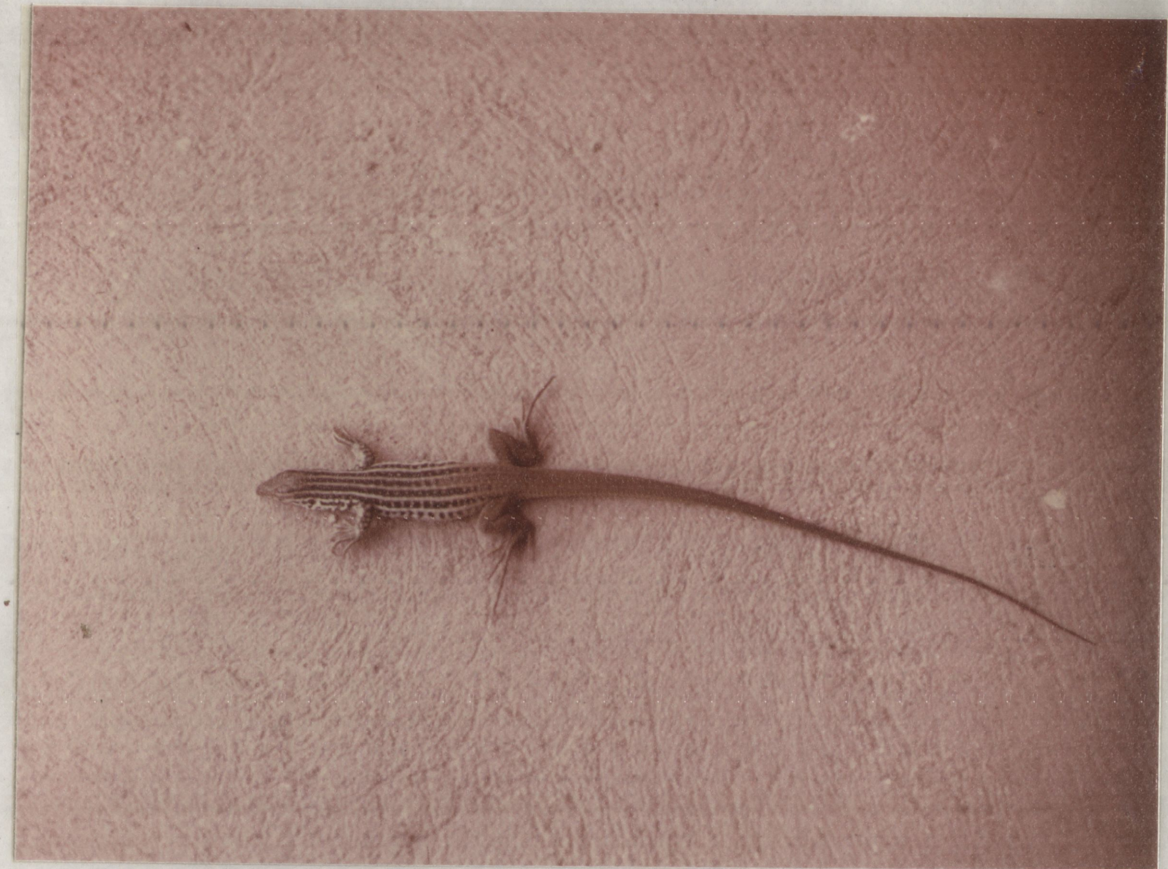

FIGURE 4a. C. scalaris.

FIGURE 4b. C. tigris.

FIGURE 5. Sector 5 at an elevation of 3900 ft.

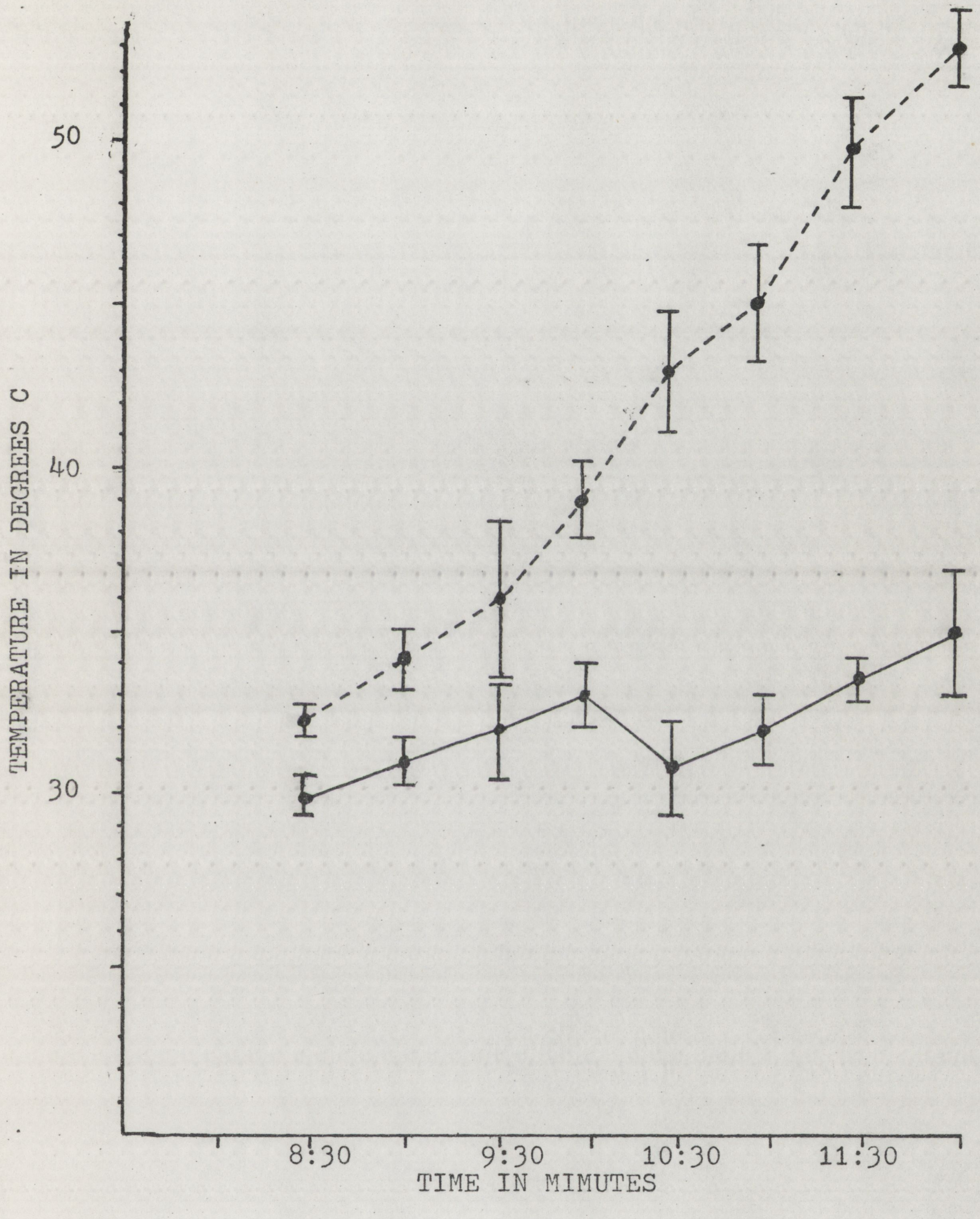

FIGURE 6. The increase in soil and air temperature at various times in the morning. The solid line represents air temperature and the broken line represents soil temperature. The vertical bars indicate the standard deviations.

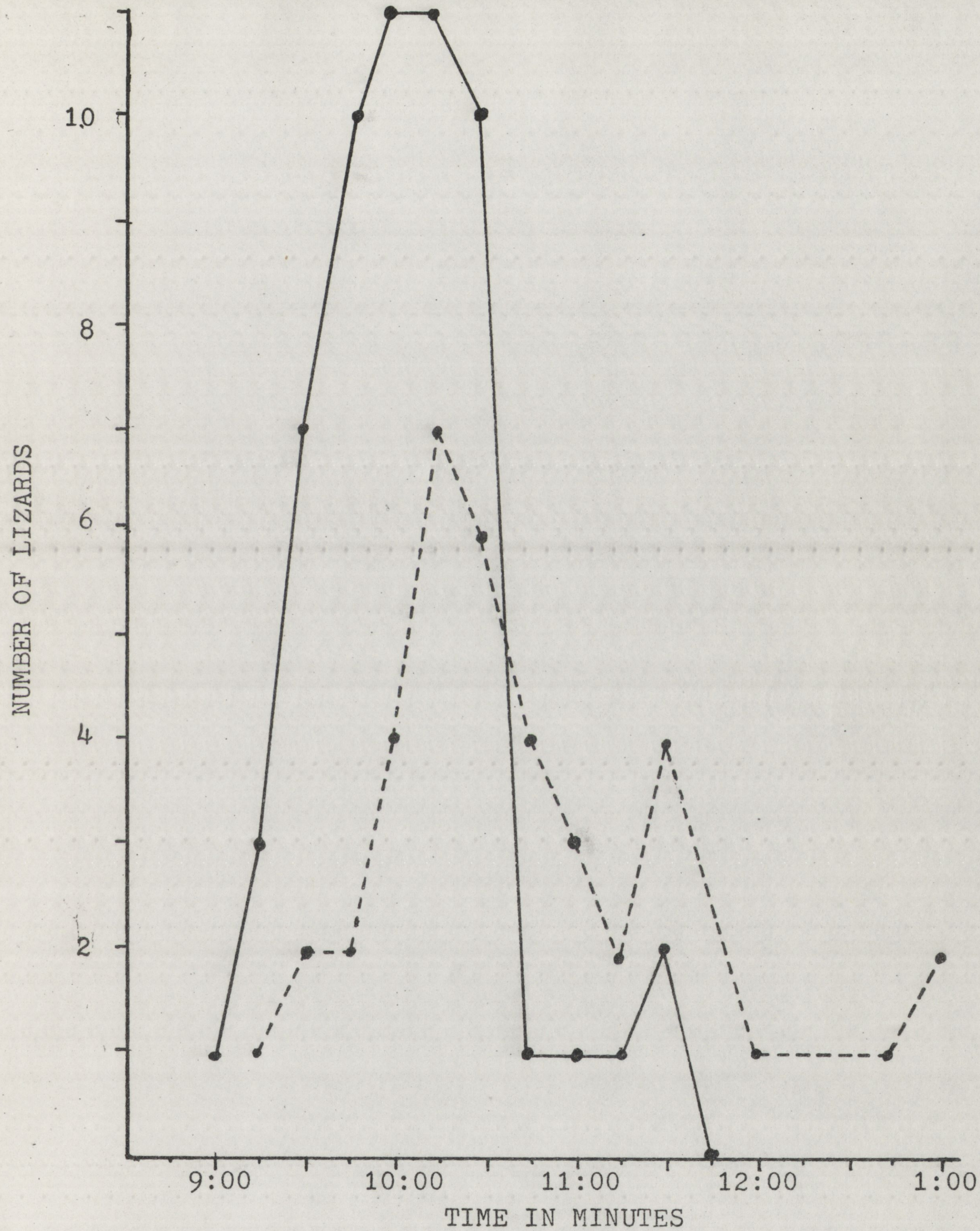

FIGURE 7. Numbers of C. tigris and C. scalaris observed at various times of the day. Solid line represents C. tigris and broken line represents C. scalaris.

TABLES

TABLE 1. Flora density for 10 sectors in Pine Canyon. The length of each sector is measured in miles and is the distance from the beginning of the first sector.

Stake			Bare ground		Vegetation: Total		Shrubs		Herbs		Tall grasses		Short grasses	
Sector no.	Elevation in feet	Miles	a[1]	b[2]	a	c[3]	a	d[4]	a	d	a	d	a	d
1	3500	0.0	131.8	65.9	68.2	34.1	24.3	35.7	28.4	41.6	14.5	21.2	1.0	1.5
2	3600	0.4	141.4	70.7	58.6	29.3	15.8	27.0	0.0	0.0	31.1	53.0	11.7	20.5
3	3700	0.8	33.7	16.1	166.3	83.1	18.1	11.4	0.0	0.0	32.8	19.7	115.4	69.0
4	3800	1.3	33.2	16.6	166.8	83.4	32.9	19.7	0.8	0.5	22.7	1.6	130.4	78.2
5	3900	1.7	63.0	31.5	137.1	68.5	37.0	27.0	1.0	0.7	56.5	41.2	42.6	31.1
6	4100	2.2	75.7	37.8	124.3	62.1	43.4	34.9	4.0	3.2	0.0	0.0	76.9	61.9
7	4400	2.5	83.9	41.9	116.1	58.1	26.9	23.2	23.1	19.9	48.6	41.8	17.5	15.1
8	4600	2.8	55.6	27.8	144.4	72.2	34.0	23.5	20.7	14.3	53.8	37.2	35.9	25.0
9	4800	3.3	49.9	25.0	150.1	75.0	63.0	42.0	0.0	0.0	87.1	58.0	0.0	0.0
10	5000	4.0	62.6	31.3	137.4	68.7	73.2	53.3	22.6	1.9	61.6	44.8	0.0	0.0

[1] total feet out of 200 ft.
[2] percentage of total measurement.
[3] percentage of total vegetation.
[4] percentage of vegetation relative to total vegetation.

TABLE 2. Summary of ecological data for Pine Canyon. Data are expressed as means and standard error. Soil moisture was determined by a Peerless moisture indicator and is expressed as percentage. Twenty readings were taken at each elevation.

Weather station elevation in feet	Maximum temperature in degrees C	Minimum temperature in degrees C	Soil moisture	Precipitation in inches
3600	43 ± 1	$23 \pm .4$	3.1	$0.4 \pm .02$
4000	$40 \pm .4$	$22 \pm .2$	4.4	$0.3 \pm .01$
4800	$37 \pm .3$	$20 \pm .4$	4.5	0.0

TABLE 3. List of major plants recorded in Pine Canyon along 10 transects. McDougall and Sperry (1951) was used to identify plant species and Dawson (1963) to identify cacti.

Plants	Elevation in feet									
	3500	3600	3700	3800	3900	4100	4400	4600	4800	5000
Herbs										
Agave lecheguilla	x	x	x	x	x	x	x			
Agave scabra										x
Dasylirion leiophyllum				x	x	x	x	x	x	x
Echinocereus stramineus	x	x								
Opuntia engelmanii	x	x	x		x	x				
Opuntia imbricata					x					
Opuntia macrocentra	x									
Opuntia rufida	x									
Shrubs										
Acacia schottii					x	x	x	x	x	
Acacia vernicosa				x	x	x	x			
Atriplex canescens					x	x				
Ephedra antisyphilitica		x	x	x	x	x	x			
Fouquieria splendens		x	x	x	x					
Jatropha dioica	x									
Larrea divaricata	x									
Parthenium argentatum					x	x				
Porlieria angustifolia						x	x			
Prosopis glandulosa				x	x					
Rhus microphylla								x	x	
Viguiera stenoloba					x	x	x	x	x	x
Yucca torreyi		x	x	x	x	x				
Grasses										
Short grasses		x	x	x	x	x	x	x	x	
Tall grasses	x	x	x	x	x	x	x	x	x	x
Nolina erumpens									x	x

TABLE 4. Numbers of *C. tigris* and *C. scalaris* found in and out of the arroyos at varying elevations

Elevation in feet	In arroyo		Out of arroyo	
	C. tigris	*C. scalaris*	*C. tigris*	*C. scalaris*
3500	3	0	14	0
3600	3	1	6	3
3700	11	0	0	0
3800	12	3	0	1
3900	3	5	0	1
4000	0	2	0	0
4100 and 4400	0	5	0	0
4500 and 4700	0	3	0	0
4800	0	2	0	0
5000	0	3	0	0

TABLE 5. Mean and range of soil temperature readings at various elevations

Elevation in feet	Soil temperature in degrees C	
	Mean	Range
3500	36	32-40
3600	37	36-39
3700	31	28-37
3800	37	42-43
4100	37	34-40
4400	37	35-39
5000	38	35-42

TABLE 6. Mean air temperature readings at different elevations

Elevation in feet	Air temperature in degrees C
3500	31
3600	34
3700	30
3800	29
3900	30
4000	32
4100 and 4400	32
4500 and 4700	31
4800 and 5000	32