THE SAGUARO TREE-HOLE MICROENVIRONMENT IN SOUTHERN ARIZONA. II. SUMMER

by

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APPROVAL BY THESIS DIRECTOR

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July 7, 1964
Date

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ABSTRACT

The microenvironment of the saguaro tree-hole was studied during the summer of 1963 in the region of Tucson, Arizona. The saguaro tree-hole modifies the external conditions of light, temperature, and humidity, altering the extremes to conditions more favorable for the animals inhabiting the tree-hole microhabitat.

Temperatures within the tree-holes are several degrees lower, and lag behind the ambient (air) temperature by two to four hours. The humidity is higher inside the tree-holes and very little of the daylight entering reaches the bottom.

Certain tree-holes retain water. These are used for drinking by vertebrates, mainly birds, and support aquatic invertebrate species.

Seven species of birds and one species of mammal were observed. Invertebrates were the most numerous animals observed. Of the large invertebrates, insects are the most abundant. Several new members were added to the list of animals known to occur in the tree-holes of the saguaro.

INTRODUCTION

The tree-hole assemblage is a discontinuous extension of the fauna specifically and the surrounding community in general (Allee, *et al.*, 1949). Tree-hole microhabitats offer opportunity for the investigation of microseres, microfood-webs, and microenvironmental adaptations. The present study was directed primarily toward the measurement of specific aspects of the microenvironment of the tree-holes of the saguaro, the giant cactus *Carnegiea gigantea* (Engl.) Br. and R. of the Sonoran Desert, and observations were also made on occupancy by animals.

Since the turn of the century, investigations of the biology of the saguaro have resulted in a number of reports on ecological and physiological aspects of the species. Some of these are relevant to the present investigation (Boyle, 1949; Cochefair, 1931; Hensley, 1954; Niering, Whittaker and Lowe, 1963).

Some recent work not directed toward the saguaro itself is of particular interest. For example, von Haartman (1957) has discussed the evolutionary significance of tree-hole nesting with special reference to birds, and tree-hole breeding mosquitoes have received recent attention by Hedeen (1955) and Kellett and Omardeen (1957). These are examples of a few studies having obvious relevance to the saguaro tree-hole microenvironment, which is initiated by birds (woodpeckers and flickers) and which harbors a distinctive species of tree-hole breeding mosquito.

Krizman (1964) has recently studied the winter microenvironment of the saguaro tree-hole and its winter inhabitants in the Tucson area in southern Arizona. The present investigation, which follows the general plan of work carried forward by Krizman during winter, embraces an examination of saguaro tree-holes and the fauna contained in them under the mid-summer environmental conditions in this area of the Arizona Upland section of the Sonoran Desert (Shreve, 1951).

METHODS AND MATERIAL

All of the data gathered are from an area centered in the Santa Cruz River Valley, which general area of study is bounded on the east by the Tanque Verde and Rincon Mountains, on the north by the Santa Catalina Mountains, on the west by the Tucson Mountains, and on the south by the City of Tucson. The investigations were concentrated on the populations of saguaros on the bajadas of these mountain ranges.

The tree-holes were reached with a 28 foot aluminum extension ladder and were examined with the aid of a flexible-necked flashlight and a swivel-based mechanic's mirror. All the samples of the contents were taken from the bottom and sides of the tree-holes and placed in appropriate containers. The depth of each hole and the aperature direction were recorded. The individual cacti were marked with a numbered aluminum tag on a wire placed around the base of the plant.

All of the instrumentation of the saguaros was in the Gate's Pass area on the east side of the Tucson Mountains, 5.5 miles west of Tucson city limits at ca. 1 mi. east of the summit of Gate's Pass. This is on the Casaday Ranch, and is referred to as the primary study area (see Krizman, 1964).

Two large (28 and 30 ft.) cacti were fitted with Labline humidity probes. One tree had a north-facing hole and the other had a hole opening to the south. The humidity was recorded at the bottom of each, and the ambient humidity was recorded at just above the aperature of the north-facing tree-hole. These probes were connected to a Labline Multi-selector, model 2206. This in turn was plugged into a Labline Electro-Hygrometer, model 2200, serial #317. Adjustments for error were made before each reading.

Temperatures in these two holes were taken with Yellow Springs Instrument air probes. These were placed at the bottom of each tree-hole, as mentioned above for the humidity sensors. Also a temperature sensor was placed just above the opening of each hole. These four probes were connected to a Yellow Springs Telethermometer (model 44TZ), in turn connected to a Yellow Springs Laboratory Recorder (model 80). The recorder was started by an Intermatic time switch supervisor (International Register Company model T 965). The time switch ran the recorder for the first fifteen minutes of every hour. Twice a day, morning and evening, the recorder was checked manually and corrected to zero error. At three to five day intervals the chart paper (Rustrak Instrument Company, style A, part # 554 16) was removed from the recorder and corrected.

The internal tissue temperatures of the saguaro were obtained with ordinary mercury thermometers (-15° to 110°C). These were placed at varying depths in the saguaro. The near-surface (sub-epidermal) temperatures were recorded at a depth of 12 mm. (0.4 in.), and the cortex temperatures at 65 mm. (2.54 in.); 135 mm. (5.27 in.) was the depth of the mercury bulb at the ribs, and 170 mm. (6.63 in.) for the temperature of the pith. The plant in which these four thermometers were placed was ca. 360 mm. (14.04 in.) in diameter.

Additional temperatures were obtained from maximum and minimum thermometers (Taylor, model 5458). These were obtained two miles east of the summit of Gate's Pass, referred to as the secondary study area. One maximum-minimum was placed on end in a north-facing tree-hole, and one in a south-facing tree-hole. Also at this site one was fixed on the north side of a saguaro at a height of five feet. A fourth maximum-minimum thermometer was placed in a government weather shelter housing the recording instruments at the principal study area on the Casaday Ranch. All were read every morning well before the daily temperature maximum.

Light intensity within two tree-holes, and outside of them, was measured with a Weston Illumination Meter (model 756). Three dates were selected to represent the seasonally changing light conditions within the saguaro tree-hole. Again, a north-facing and a south-facing saguaro tree-hole were used. These were located in the secondary study area.

The data were gathered between the middle of May and the end of August, 1963. Three extended observations involving manual operation of the instruments were made in Gate's Pass. These were on June 9-June 11, June 21-June 23 and July 15-July 17, 1963.

MICROENVIRONMENT OF THE TREE-HOLE

Temperature

The month of May 1963 was the second warmest since 1886, but the average daytime cloudiness was higher than usual. June was the coolest since 1951 and had an unusually low percentage of cloud cover. The average temperature for July was the highest since 1957 with an average daily maximum of 99.8°F. While August was normal in most aspects, it was the first August since 1923 and the second since 1889 that the temperature did not reach 100°F (U. S. Weather Bureau, Tucson, Arizona).

Temperature within the saguaro tree-hole is in a constant state of change throughout the summer. The temperature in the tree-hole is directly controlled by two principal factors: 1) the external or ambient air temperature, and 2) the temperature of the saguaro tissue. All three (the tree-hole temperature, the air temperature and the saguaro temperature) go through two cycles daily which are controlled by solar radiation.

The air temperature changes most rapidly. The north-facing air probe registered its maximum near sunset. The south maximum, during late afternoon, was associated with the time when the sun is still shining in the opening of the tree-hole.

Throughout the summer the south-facing tree-hole is warmer because the south side of the plant receives more direct solar radiation during the day. While the north side has the higher ambient temperatures (from back-radiation from rocky slopes), it has the lower tree-hole temperatures. This is due to less direct tissue heating by solar radiation. The tree-hole temperatures usually lag two to four hours behind the ambient (air) temperatures in reaching their extremes (Fig. 1, Table 1).

Table 1

Fifty-eight hour temperature recordings of north-facing and south-facing saguaro tree-holes, north and south ambient, and saguaro tissue. Data recorded manually from June 9 to June 11, 1963 at primary study site in Tucson Mountains. Graphed in Figs. 1 and 2.

Time and Date	Temperature (^{o}C) Tree-hole		Ambient		Tissue			
	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
1963 6/9								
1 pm	24.0	25.1	30.0	29.0	27.5	26.9	25.8	
2	25.0	26.0	34.0	30.6	28.7	27.1	26.2	
3	25.5	27.0	33.5	30.2	29.6	28.0	26.8	
4	26.3	27.0	34.0	31.5	30.8	29.0	27.0	
5	27.0	27.0	36.0	29.0	31.7	30.0	27.8	
6	27.6	28.2	34.1	28.8	32.5	30.1	28.2	
7	28.0	29.0	27.5	27.6	32.1	31.5	28.9	
8	28.1	29.0	26.1	26.1	29.8	31.2	30.3	
9	27.0	27.6	23.5	23.0	30.3	31.0	28.9	
10	28.0	27.4	22.0	22.0	28.3	30.1	29.1	
11	27.0	28.0	21.0	20.5	26.8	29.0	29.9	
12	27.0	27.7	19.0	19.0	26.8	28.5	29.4	
6/10								
1 am	27.0	27.0	16.5	16.0	24.9	27.8	29.0	
2	26.0	26.2	16.5	16.0	23.7	27.0	28.9	
3	25.1	25.3	16.3	16.0	22.6	25.7	28.0	
4	24.0	24.7	16.0	16.0	21.7	24.6	27.3	

[1]Sub-epidermis

Table 1 (continued)

Temperature (°C)

Time and Date	Tree-hole		Ambient		Tissue			
	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
1963 6/10								
5 am	23.0	23.9	16.0	16.0	20.8	24.0	26.5	
6	22.8	23.1	19.0	20.5	20.3	23.5	26.5	
7	22.1	22.9	22.6	23.5	21.5	23.1	25.5	
8	22.0	23.0	25.8	26.3	23.3	23.7	24.9	
9	22.0	23.1	26.9	29.0	24.5	24.4	25.0	
10	22.2	24.0	28.2	30.0	25.5	25.0	24.9	
11	24.0	24.5	29.0	33.0	26.4	26.0	25.3	
12	24.0	26.0	30.0	31.1	28.2	27.0	26.0	
1 pm	24.1	26.1	31.0	31.9	28.8	27.5	26.4	24.8
2	25.6	27.5	33.0	32.0	29.4	28.0	26.9	24.8
3	26.1	27.0	34.0	32.0	30.4	29.0	27.7	25.8
4	27.5	29.0	34.0	31.5	31.3	29.5	27.9	26.3
5	28.0	29.0	34.0	30.0	32.4	31.0	28.9	28.8
6	28.0	29.1	31.5	29.0	32.8	31.2	29.1	28.3
7	28.5	29.5	28.0	28.0	32.2	32.0	29.9	28.9
8	28.9	29.5	26.9	26.7	30.8	31.5	29.9	29.8
9	28.9	29.0	25.8	25.1	29.3	31.0	30.9	30.8
10	28.5	29.0	24.9	25.0	28.7	31.0	30.9	30.8
11	28.0	28.6	23.0	23.0	28.1	30.0	30.9	30.8
12	28.0	28.5	23.0	22.8	27.3	29.5	30.4	30.3

[1]Sub-epidermis

Table 1 (continued)

Temperature (°C)

Time and Date	Tree-hole		Ambient		Tissue			
1963 6/11	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
1 am	27.2	28.0	22.0	22.0	26.3	29.0	30.0	30.0
2	27.0	27.5	21.4	21.1	25.3	28.0	29.9	29.8
3	26.2	27.0	21.0	21.0	25.3	28.0	29.5	29.4
4	26.0	26.1	20.0	20.1	24.6	27.0	28.9	28.8
5	25.1	26.0	19.5	19.5	24.3	27.9	28.4	28.8
6	25.0	25.1	23.1	24.5	23.8	26.0	28.0	27.8
7	24.5	25.0	25.5	26.1	24.7	27.0	27.7	27.3
8	24.5	25.0	26.9	26.1	25.4	26.0	27.3	26.9
9	24.5	25.4	27.0	28.0	26.5	27.0	27.2	26.7
10	25.0	26.0	29.0	30.1	27.7	27.3	27.9	26.2
11	25.5	26.6	30.8	31.0	28.8	28.2	27.9	27.3
12	26.0	27.5	30.9	32.0	29.4	29.0	28.2	26.8
1 pm	26.9	28.1	32.2	32.1	30.3	29.5	28.9	26.8
2	27.0	28.5	35.0	32.1	31.2	30.0	28.9	27.3
3	28.0	29.1	35.1	33.9	32.3	31.0	29.9	27.8
4	28.7	29.9	36.1	32.0	32.9	31.8	30.1	28.8
5	29.0	30.0	35.0	30.5	33.8	32.4	30.9	29.6
6	30.0	30.5	33.6	29.5	34.4	34.4	30.9	30.0
7	30.0	30.1	27.1	27.0	33.3	33.5	31.9	30.8
8	30.0	30.0	25.5	25.0	31.6	33.0	31.9	31.8

[1]Sub-epidermis

Table 1 (continued)

Time and Date	Tree-hole North	Tree-hole South	Ambient North	Ambient South	Tissue Sub-ep[1]	Tissue Cortex	Tissue Ribs	Tissue Pith
1963 6/11 9 pm	30.0	29.5	24.0	24.0	29.8	32.0	32.9	31.8
10	29.5	29.0	23.0	22.0	29.3	31.0	31.9	31.8
11	29.0	29.0	23.5	22.5	27.3	30.2	31.9	31.8

Temperature (°C)

[1]Sub-epidermis

The tissue temperature also lags behind the air temperature. The temperature beneath the epidermis lags by one to three hours behind the air, and each region inward (the cortex, ribs, and pith) lags one hour behind the region out from it. Also with the increase in depth, the amplitude of the extremes at each level is reduced. Thus the tree-hole reaches a maximum or minimum temperature at approximately the same time as the cortex and the ribs--the site of the usual internal position of the tree-hole. The tree-hole maximum temperature is generally a few degrees lower than an undisturbed section of the saguaro of a comparable depth (Fig. 2, Table 1).

Early June.-- During the early summer (June 9-June 11) the maximum and minimum ambient temperatures were as mentioned before for early June, i.e., associated with near sunset and near sunrise. The average north-facing ambient maximum was 35.0°C and the south ambient mean maximum temperature was 32.5°C while both had an average minimum of 17.8°C.

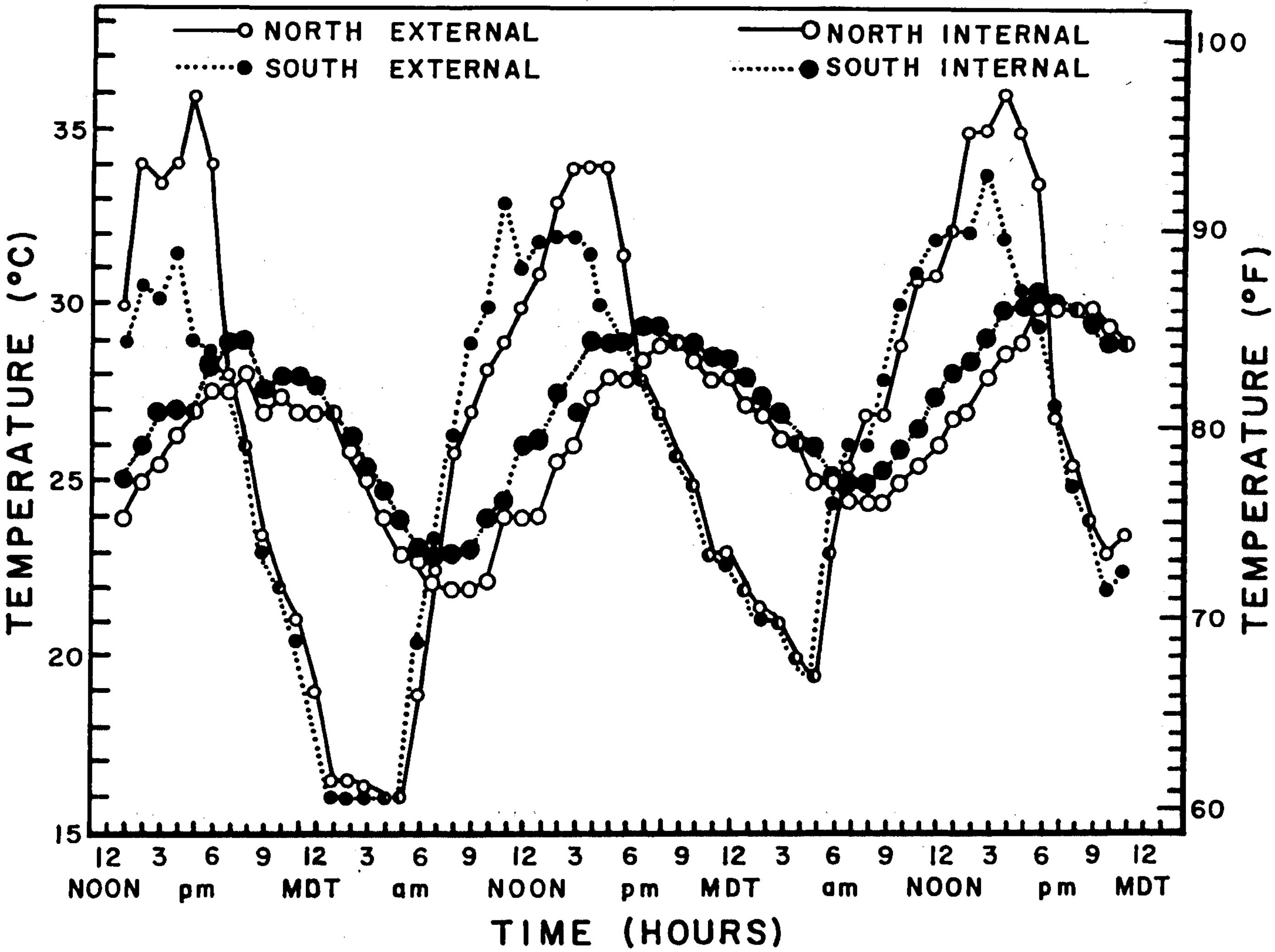

Fig. 1. Hourly summer temperatures for air outside and inside a south-facing and a north-facing saguaro tree-hole, June 9 to June 11, 1963. Data in Table 1.

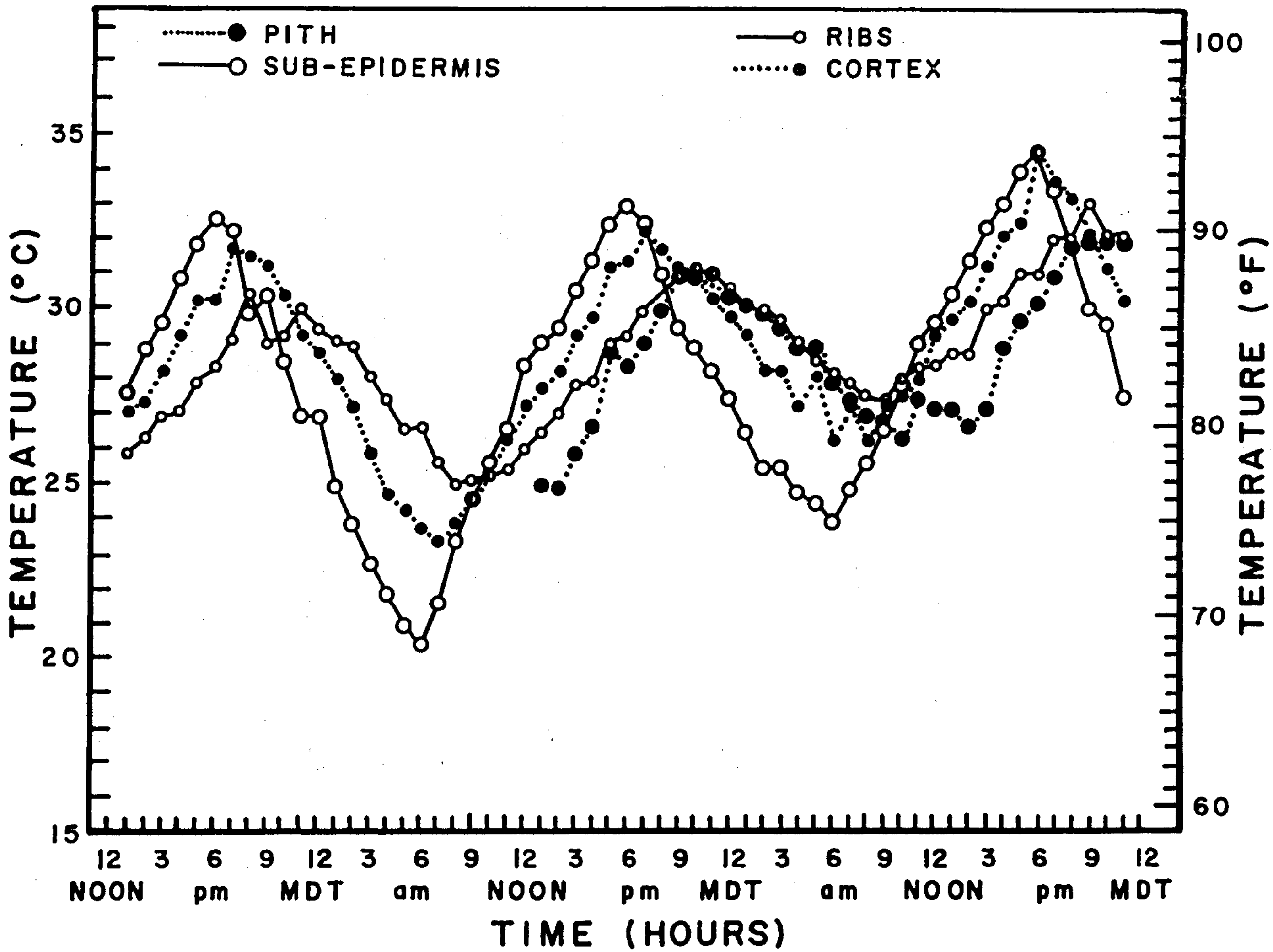

Fig. 2. Hourly summer temperatures of internal cactus tissues surrounding saguaro tree-holes, June 9 to June 11, 1963. See Table 1 and p. 4.

Table 2

Fifty-seven hour temperature recordings of north-facing and south-facing saguaro tree-holes, north and south ambient, and saguaro tissue. Data recorded manually from June 21 to June 23, 1963 at primary study site in Tucson Mountains. Graphed in Figs. 3 and 4.

Time and Date	Temperature (°C)							
	Tree-hole		Ambient		Tissue			
	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
1963 6/21								
1 pm	30.1	33.9	35.0	36.0	33.3	33.2	31.9	
2	31.0	33.0	37.0	36.8	34.3	33.0	33.4	31.7
3	35.2	33.8	36.0	35.1	35.1	34.0	32.9	31.9
4	32.5	34.0	36.6	35.1	36.1	34.3	33.4	32.6
5	33.0	34.5	35.0	34.9	37.9	35.2	33.9	33.0
6	34.3	35.0	35.0	33.5	37.3	36.0	34.2	33.7
7	33.9	34.9	30.0	30.1	36.3	36.5	34.9	34.2
8	34.0	34.5	28.0	28.0	34.9	36.0	35.1	34.8
9	33.0	33.9	27.1	27.0	33.3	35.5	35.6	34.8
10	33.0	33.0	25.0	25.0	31.5	34.0	35.4	34.8
11	32.5	32.0	26.0	26.0	30.3	33.3	34.9	34.8
12	32.0	31.1	25.0	25.0	28.7	32.2	34.8	34.8
6/22								
1 am	32.0	31.3	22.1	22.0	29.1	32.0	33.9	34.0
2	31.3	31.0	20.0	19.5	27.9	31.0	33.5	33.4
3	30.2	30.0	18.0	17.0	26.3	29.9	32.9	32.8
4	29.9	29.0	16.5	16.0	25.3	29.0	32.0	32.2

[1]Sub-epidermis

Table 2 (continued)

Time and Date	Temperature (°C) Tree-hole		Ambient		Tissue			
	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
1963 6/22								
5 am	28.9	28.0	18.5	18.9	24.1	28.0	31.3	31.5
6	28.0	27.5	26.0	26.8	23.5	27.0	30.6	30.8
7	27.1	27.0	31.2	29.9	24.3	26.5	29.8	29.8
8	26.9	27.0	31.0	29.6	26.3	27.0	28.9	28.8
9	26.6	26.0	33.0	30.0	27.3	27.4	28.9	28.8
10	26.8	27.8	34.9	32.4	28.9	28.4	28.9	28.1
11	27.0	28.2	35.0	34.5	30.3	29.3	29.1	28.3
12	27.0	29.5	34.0	35.0	31.0	30.0	29.9	29.8
1 pm	28.0	30.1	34.8	34.5	31.7	31.0	29.9	28.8
2	27.7	31.0	37.0	34.5	32.7	31.3	30.8	29.7
3	29.0	31.3	37.5	36.0	33.9	32.1	30.9	29.9
4	30.0	32.0	37.0	35.0	34.8	33.0	31.7	30.8
5	30.1	32.5	37.6	34.9	35.3	34.0	31.9	30.9
6	31.0	33.0	35.0	32.1	36.3	34.8	32.7	31.8
7	31.6	33.0	30.9	30.2	35.3	35.0	33.0	32.3
8	32.0	33.0	29.5	29.6	34.0	35.0	33.9	32.9
9	32.0	32.9	28.8	28.9	32.6	34.0	33.9	33.2
10	32.0	32.5	26.0	27.0	31.3	33.5	33.9	32.8
11	31.4	31.6	26.0	26.0	30.3	32.8	33.9	33.4
12	31.2	31.4	25.0	25.0	29.3	32.0	33.9	32.8

[1]Sub-epidermis

Table 2 (continued)

Time and Date	Temperature (°C)							
	Tree-hole		Ambient		Tissue			
	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
1963 6/23								
1 am	31.0	31.0	24.0	24.0	28.3	31.0	32.9	32.8
2	30.0	30.1	24.3	24.5	28.6	30.0	32.4	32.4
3	30.0	30.0	23.0	23.0	27.0	29.1	31.9	31.8
4	29.2	29.0	20.8	20.5	26.0	28.8	31.1	31.3
5	28.6	28.5	20.5	21.0	24.9	28.0	30.8	30.8
6	28.0	28.0	27.0	26.5	24.8	27.1	29.9	29.8
7	27.5	27.4	30.0	29.0	25.5	27.0	29.4	29.6
8	27.1	27.5	31.0	30.8	28.3	27.2	28.9	28.8
9	27.0	28.0	33.5	34.0	28.3	28.0	28.9	28.8
10	27.0	28.0	34.0	32.2	30.3	30.0	28.9	28.7
11	27.6	29.0	34.0	35.0	30.6	30.0	29.9	28.8
12	28.0	30.0	35.0	35.9	31.3	30.5	29.9	28.8
1 pm	29.0	31.0	36.2	36.0	32.7	31.4	30.9	29.8
2	29.3	31.9	38.2	36.1	33.8	32.2	31.1	30.0
3	30.0	32.5	37.0	35.7	34.7	33.0	31.9	30.8
4	30.8	33.0	37.5	35.0	35.5	34.0	31.9	31.0
5	31.0	33.2	37.5	34.9	36.3	34.1	32.8	31.8
6	32.0	33.8	33.0	33.0	36.9	35.1	33.1	32.8
7	32.0	33.9	32.0	31.3	36.8	35.8	33.9	33.0
8	32.5	33.9	29.9	29.5	34.3	35.0	33.9	33.8
9	33.0	33.2	27.2	27.0	32.7	34.6	34.4	33.9

[1]Sub-epidermis

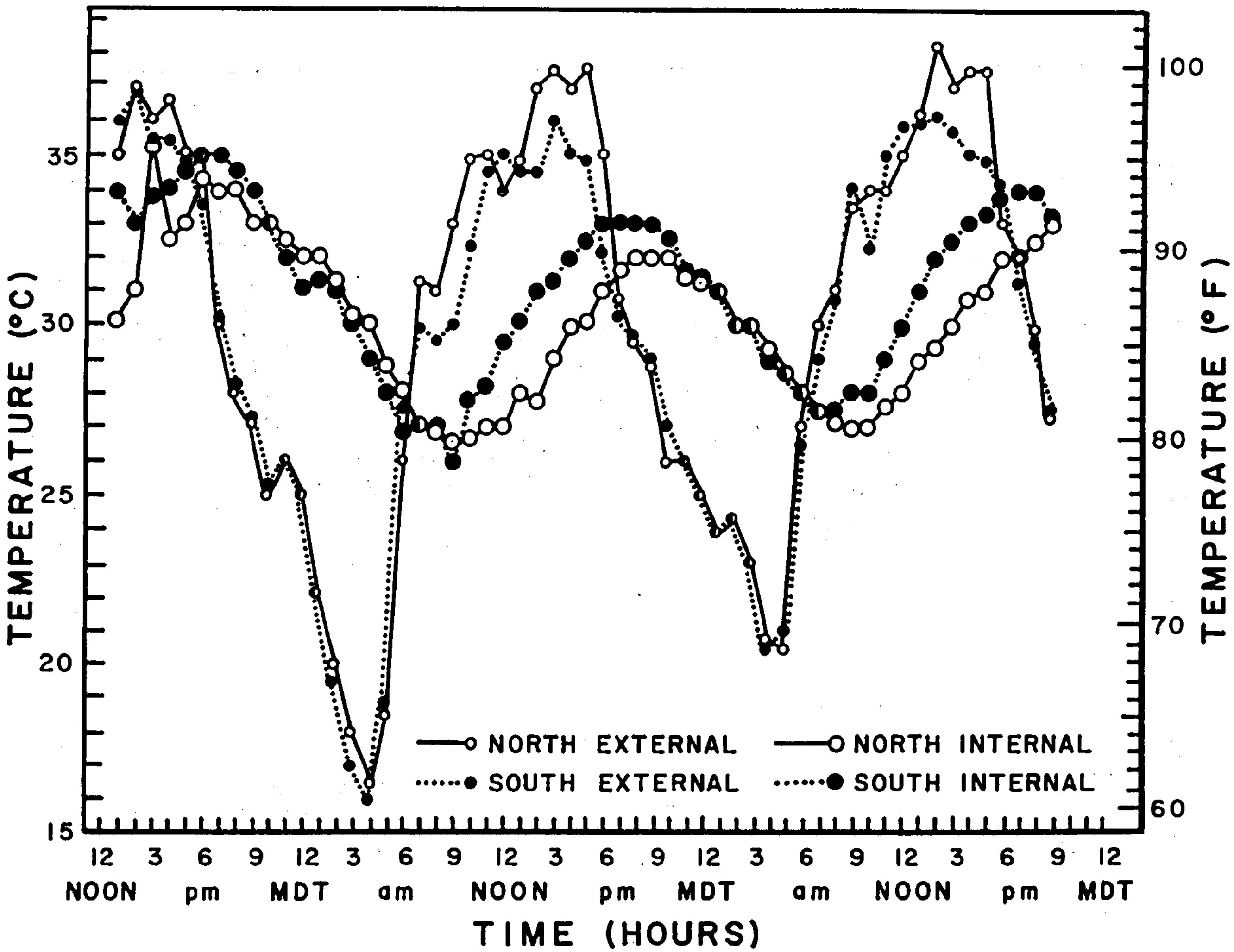

Fig. 3. Hourly summer temperatures for air outside and inside a south-facing and a north-facing saguaro tree-hole, June 21 to June 23, 1963. Data in Table 2.

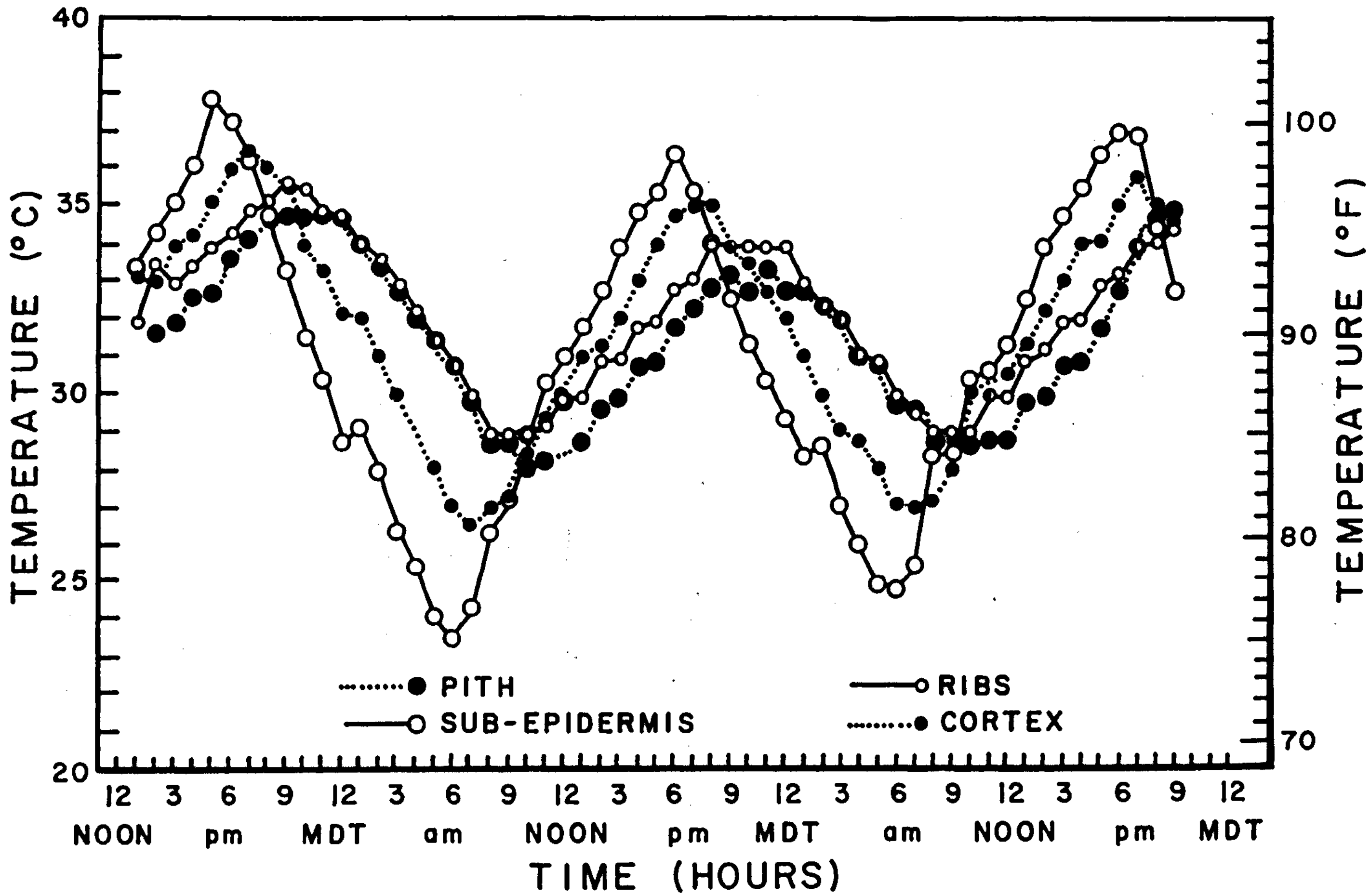

Fig. 4. Hourly summer temperatures of internal cactus tissues surrounding saguaro tree-holes, June 21 to June 23, 1963. See Table 2 and p. 4.

The average saguaro tissue temperatures differed from the north ambient temperatures as follows: (1) beneath the epidermis the maximum was 1.75°C lower and the minimum was 4.3°C higher than ambient, and lagged behind the ambients by about 1.5 hours; (2) the cortex had a maximum 2.48°C lower and a minimum 6.8°C higher, and the lag was approximately three hours behind the ambient; (3) the ribs were 3.6°C lower than the north ambient maximum and 8.3°C warmer than the north ambient minimum, and lagged behind the ambient by four hours (one hour behind the cortex); (4) while the pith maximum was 3.8°C lower and the pith minimum 8.4°C higher than the average north ambient extremes and showed a lag of about five hours behind ambient and about one hour behind the ribs (Fig. 2, Table 1).

The saguaro tree-holes during this period show separation of the ambient and internal air maxima on the order of 2-3 hours, with a temperature 6.0°C lower than air in the north-facing tree-hole (35.0°C to 29.0°C) and 2.8°C lower than air in the south-facing tree-hole (32.5°C to 29.7°C). The minima also lag by about three hours. The difference in the minima showed the north tree-hole temperature to be warmer by 5.5°C than the external, and the south internal temperature to be warmer by 5.8°C than the ambient (see Fig. 1, Table 1).

Thus at this early part of the summer, these tree-holes show a drop on the average of 6.0°C in the north side and 2.8°C in the south side from the ambient maximum and a difference in average minima of 5°C-6°C from the ambient minimum temperature. These conditions take about three hours to be reached.

Late June.-- During late June (June 21-June 23) again the north ambient was warmer (Fig. 3, Table 2). A comparison of the average daily maxima shows that the north was 37.7°C and the south 34.3°C for the period. The minima were between 18.2°C and 18.5°C, indicating a general increase of roughly 2.0°C in the maxima and 1.0°C in the minima over the preceding twelve days.

The sub-epidermis temperature of the saguaro had an average maximum temperature 0.5°C less than the north ambient. It should be noted that the first observation of a tissue temperature higher than ambient was recorded at this time (Fig. 4, Table 2). The sub-epidermal lags were on the order of one hour. The cortex had a maximum 2.0°C less than the ambient and a minimum 8.2°C higher; these were reached about two hours after the extremes of the ambient. The ribs were on the average 3.0°C less than the north side ambient and a minimum 10.4°C warmer; and about 3.5 hours were required for this to take place. The pith had an average maximum 3.7°C less than the ambient and there was a difference of 10.2°C in minima (see Fig. 4, Table 2).

The tree-holes show a uniform lag of four hours at both the maximum and minimum temperature extremes. The differences at the maximum level show the north tree-hole temperature to be lower than the ambient by 4.6°C (37.7° to 33.1°) and the south to be less by 0.4°C (34.3° to 33.9°). Again the north had the higher ambient maximum average, yet the lower tree-hole temperatures. Both holes were about 8.4°C warmer than their comparative ambient minima (Fig. 3, Table 2).

Therefore, in the twelve days that had passed, since June 11, the tree-hole temperatures were increasing at a rate of change almost twice that of the ambient. The tree-hole air temperatures were increasing on an average 4.2°C higher than during early June, while the average ambient maximum was only 2.25°C higher.

Mid-July.— July 15–July 17 (Figs. 5 and 6, Table 3) fell within the hottest two weeks of the summer. The step progression of the temperatures reached the highest point under observation at this time. The north side ambient maxima averaged 40.5°C and those on the south averaged 39.0°C. This was an increase of 2.8°C for the north and 4.7°C for the south over the June 21–June 23 period. The minima were about 7.0°C higher than the late June period, falling around 25.5°C.

By this time the sub-epidermis tissue had achieved an average maximum temperature 1.0°C higher than the north ambient. (The importance of this cumulative heat capacity can best be realized during the extreme winter conditions; see Krizman, 1964). The minimum sub-epidermal average was 3.3°C warmer than the north side ambient average. Both the maximum and the minimum lagged one hour behind the ambient. The lag was stepped up to two hours in the cortex and the average maximum was 0.63°C less than the ambient, and the minimum was 5.87°C warmer. The lag was doubled at the depth of the ribs and increased the temperature differences. The maximum rib average was 2.0°C less than the air maximum and the minima at this depth were 7.7°C warmer. The pith showed the greatest deviation from the average air maximum, at 2.1°C lower. However, the pith was only 7.0°C warmer than the average ambient minimum. The high temperature of this period brought about the first observation of a nocturnal separation of the rib and pith temperatures. This indicates further that the thermometers were placed correctly (see Fig. 6, Table 3).

Table 3

Forty-seven hour temperature recordings of north-facing and south-facing saguaro tree-holes, north and south ambient, and saguaro tissue. Data recorded manually from July 15 to 17, 1963 at primary study site in Tucson Mountains. Graphed in Figs. 5 and 6.

Time and Date	Temperature (°C)							
	Tree-hole		Ambient		Tissue			
	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
1963 7/15 12 am	34.8	36.3	38.0	38.4	36.3	36.0	36.0	35.8
1 pm	35.0	37.3	39.5	40.0	37.4	37.0	36.9	35.9
2	35.5	37.9	38.0	40.0	38.1	37.0	36.9	36.5
3	35.3	38.2	40.0	39.0	39.3	38.0	37.4	36.8
4	36.0	38.5	38.0	38.0	40.2	38.8	37.9	37.8
5	37.5	39.0	40.0	37.1	40.8	39.2	38.1	37.8
6	38.0	39.1	37.0	34.0	40.7	40.0	38.9	38.6
7	38.0	39.0	34.1	34.0	39.5	40.0	38.9	38.8
8	38.0	39.8	32.5	32.9	38.3	39.4	39.0	38.8
9	38.0	38.0	32.5	31.5	36.3	38.2	39.1	38.9
10	37.5	37.5	31.0	31.0	35.3	37.5	38.9	38.9
11	37.0	36.8	30.0	29.9	34.3	36.8	38.9	38.8
12	36.0	36.0	28.2	28.4	33.5	36.0	37.9	38.3
7/16 1 am	35.0	35.0	26.0	26.2	32.3	35.0	37.4	37.8
2	34.6	34.3	25.0	25.1	31.3	34.1	36.9	37.3

[1] Sub-epidermis

Table 3 (continued)

Time and Date	Temperature (°C)							
	Tree-hole		Ambient		Tissue			
1963 7/16	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
3 am	35.0	34.9	25.6	25.7	30.3	33.2	35.9	36.8
4	33.0	33.0	25.5	25.1	29.5	32.5	35.6	35.8
5	32.1	32.0	24.9	24.5	28.8	32.0	34.9	35.1
6	31.5	31.8	28.0	28.0	28.3	31.0	34.2	34.8
7	30.9	31.1	29.0	30.0	29.1	31.0	33.7	33.8
8	30.2	31.0	32.0	33.0	29.8	31.0	33.0	32.8
9	30.2	31.0	33.4	36.0	31.2	31.3	32.9	32.7
10	30.5	32.0	37.8	40.0	32.3	32.0	32.9	32.3
11	31.0	33.0	36.1	37.0	33.3	33.0	31.9	32.6
12	32.0	34.2	35.0	35.0	34.6	34.0	33.9	32.8
1 pm	33.0	35.0	37.5	38.6	34.7	34.6	34.1	33.7
2	33.7	36.0	35.0	36.0	36.6	35.1	34.9	33.8
3	34.5	36.4	38.0	37.8	37.5	36.1	35.2	34.8
4	36.0	37.4	41.0	38.0	38.7	37.0	35.9	35.8
5	36.0	37.5	40.0	38.0	40.3	38.0	36.2	35.8
6	36.5	38.0	39.0	36.4	41.3	39.0	36.9	36.8
7	37.0	38.0	35.0	38.0	40.3	39.8	37.7	36.8
8	37.2	38.0	34.0	34.0	38.3	39.0	37.9	37.8
9	37.0	38.0	32.8	32.9	37.1	38.0	38.0	37.8
10	37.0	37.4	31.8	31.8	37.1	37.7	38.0	37.9

[1]Sub-epidermis

Table 3 (continued)

Time and Date	Temperature (°C)							
	Tree-hole		Ambient		Tissue			
	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith
1963 7/16 11 pm	36.9	36.8	29.8	29.5	34.9	37.9	37.9	37.9
12	36.0	36.0	28.9	28.5	33.8	36.0	37.8	37.8
7/17 1 am	35.0	35.0	28.1	28.0	32.7	35.2	37.3	37.3
2	34.8	34.5	27.7	27.5	32.0	34.4	36.8	36.8
3	34.0	34.0	27.5	27.4	31.3	34.0	35.9	36.8
4	33.0	33.0	26.8	26.5	30.3	33.0	35.4	35.8
5	32.5	32.5	26.2	26.0	29.9	32.5	34.8	35.1
6	32.0	32.0	30.0	30.0	29.3	32.0	34.0	34.8
7	31.7	31.9	31.8	32.0	30.1	31.8	33.9	34.2
8	31.2	31.5	34.0	34.9	31.2	32.0	33.5	33.8
9	31.0	32.0	38.8	37.0	32.3	32.8	33.4	33.0
10	31.6	33.0	37.5	38.0	33.4	33.1	33.9	32.9

[1]Sub-epidermis

The north-facing tree-hole had a lag of 3.5 hours for both the maxima and minima. The maximum was 2.8° lower than the ambient (40.5°C to 37.7°C) and the minimum was 5.1° warmer (25.5°C to 30.6°C). The south-facing tree-hole had only a slight depression of the maximum temperature in the tree-hole, 0.1° (39.0°C to 38.9°C), and the minimum average was 6.2°C higher (25.25°C to 31.5°C). The south hole lagged about four hours behind the ambient (Fig. 5, Table 3).

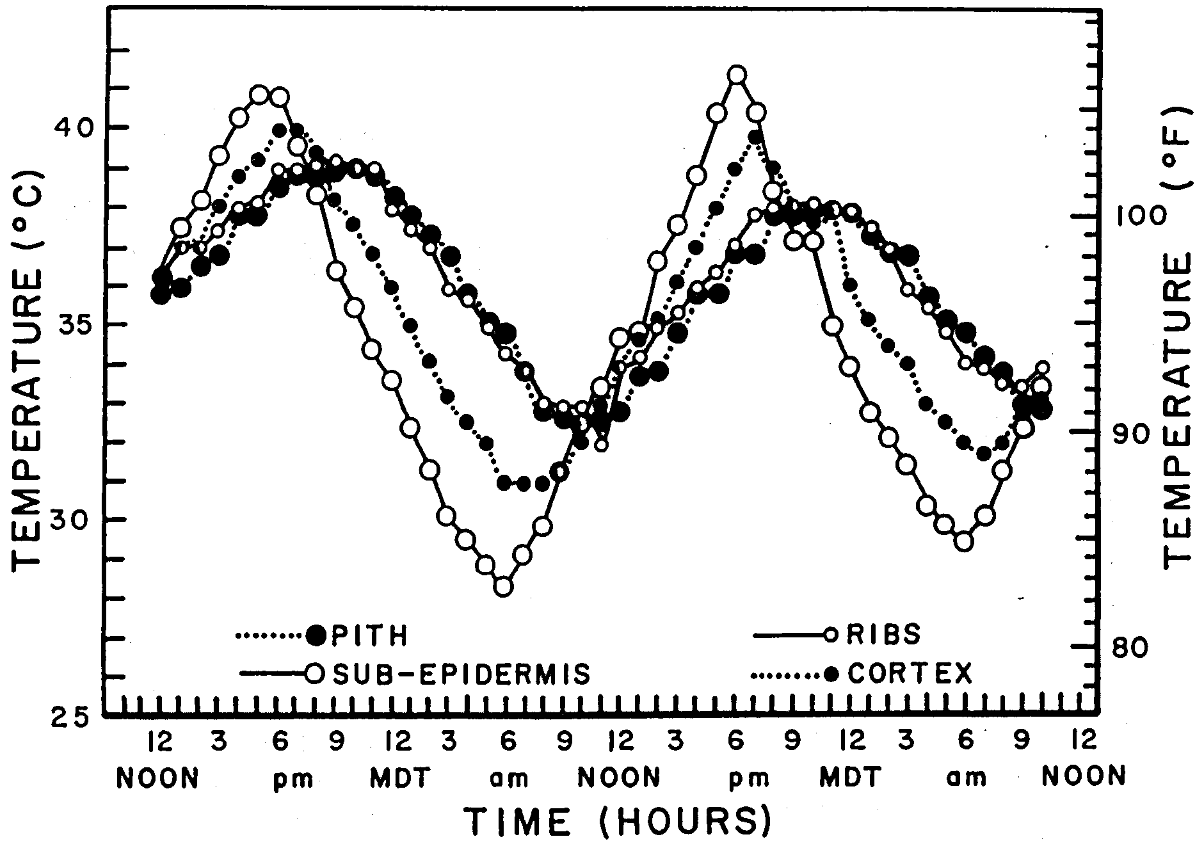

Fig. 5. Hourly summer temperatures for air outside and inside a south-facing and a north-facing saguaro tree-hole, July 15 to July 17, 1963. Data in Table 3.

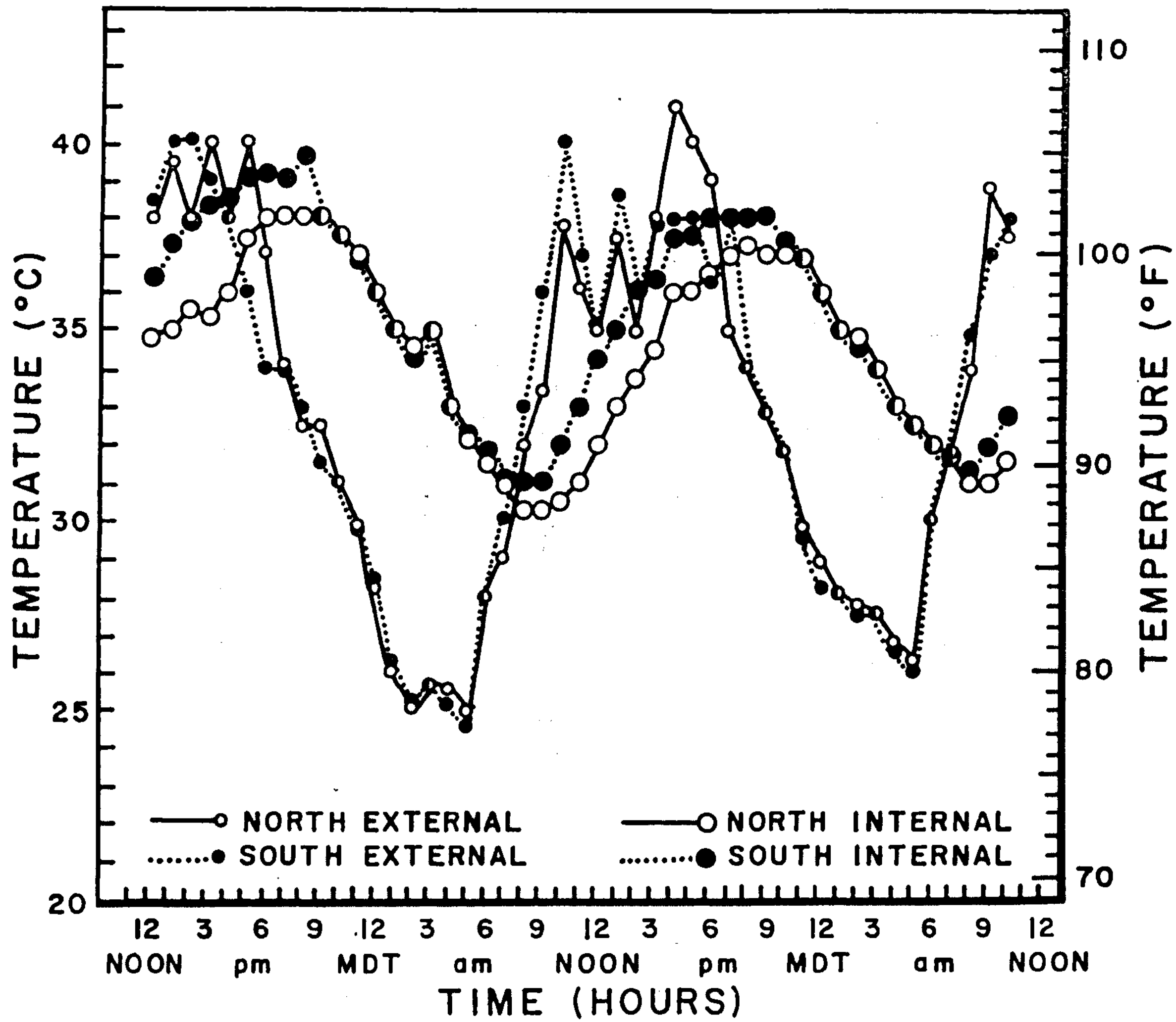

Fig. 6. Hourly summer temperatures of internal cactus tissues surrounding saguaro tree-holes, July 15 to July 17, 1963. See Table 3 and p. 4.

A comparison of these data with those for June 21-June 23, shows the rate of increase within the tree-holes for the period to be fairly constant, 4.2° for end of June and 4.8° for July; while the ambient temperature increases from 2.2°C at the end of June to 3.8°C in July. The tree-holes show a temperature increase at the maximum temperature level which is relatively constant. Therefore, the lack of great irregularity in the microclimate makes it easier for animals inhabiting saguaro tree-holes to adjust physiologically. The damping of the extremes also adds to the effectiveness of the tree-hole micro-environmental modification.

The modification (tree-hole temperature compared to ambient temperature) of the maximum temperature level between the summer observations is not level. The modification becomes less from observation to observation (see Fig. 7, Table 4), and thus the maximum tree-hole temperatures approach and nearly meet the ambient temperature. However, the change between each observation at the minimum temperature level (tree-hole temperature compared to ambient temperature) is constant (see Fig. 7, Tables 4 and 5), and the difference between minimum inside and minimum outside remains more or less the same.

Even though the tree-hole is losing its effectiveness in modifying the tree-hole maximum thermal conditions, the maximum tree-hole temperature (tree-hole temperature compared to tree-hole temperature) increases (early June, late June, mid-July) uniformly (see Fig. 8, Tables 4 and 5). However, the ambient (see Fig. 8, Tables 4 and 5) and the minimum tree-hole temperature (see Fig. 8, Tables 4 and 5) do not increase uniformly from level to level.

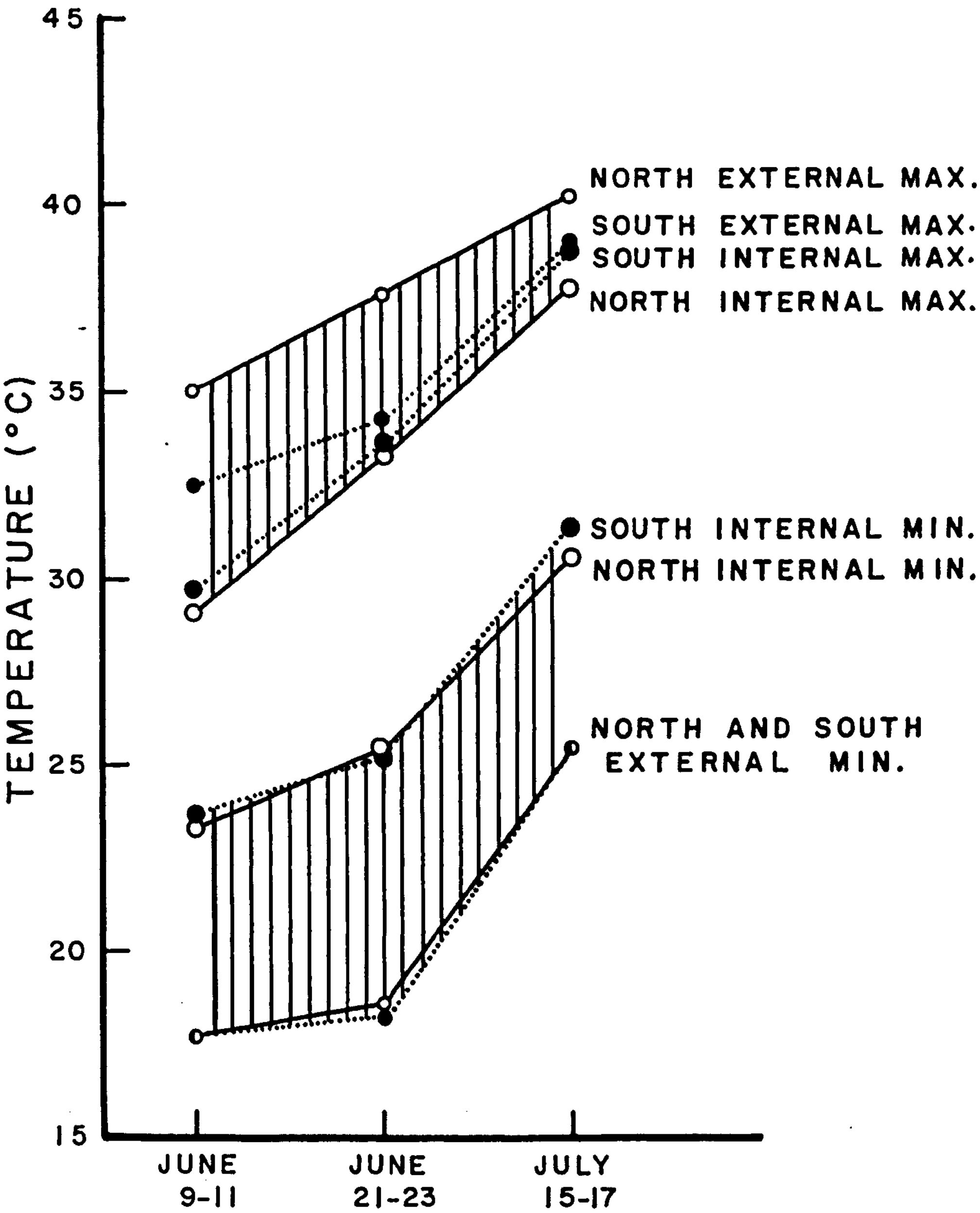

Fig. 7. Average maximum and minimum ambient(outside) temperatures for north and south sides of saguaros and north-facing and south-facing saguaro tree-holes during the summer of 1963. Data in Table 4.

Table 4

Average maximum saguaro tree-hole ambient temperature recorded at the primary study site in the Tucson Mountains during the three manual observation periods: June 9 to 11, June 21 to 23, and July 15 to 17, 1963. Graphed in Figs. 7 and 8.

Temperature (°C)

Date	Tree-hole	North Difference	Ambient	Tree-hole	South Difference	Ambient
June 9-11	29.0	-6.0	35.0	29.7	-2.8	32.5
Difference	4.1	—	2.7	4.2	—	1.8
June 21-23	33.1	-4.6	37.7	33.9	-0.4	34.3
Difference	4.6	—	2.8	5.0	—	4.7
July 15-17	37.7	-2.8	40.5	38.9	-0.1	39.0

Maximum-minimum temperatures were recorded on the bajada west of Tucson (east of Gate's Pass). Also one maximum-minimum thermometer was maintained in a standard weather shelter at the primary study area (Casaday's) in Gate's Pass. Official temperatures were obtained from the U. S. Weather Bureau Office at Tucson International Airport and from the University of Arizona at the Solar Radiation Laboratory.

During the eleven day period from 12:00 noon July 14 to 12:00 pm July 26, maximum temperatures for the calendar year 1963 were recorded for all stations at Tucson. Both official weather stations recorded their highest temperatures on July 25—Tucson Airport (107°F = 41.7°C) and University of Arizona (110°F = 43.3°C). Also both the north and the south highs were reached this date: north-facing hole (105.6°F = 40.9°C), and south-facing hole (105.8°F = 41.0°C). The maximum air temperature recorded at the weather station in Gate's Pass was 111.8°F (44.3°C) on July 23. This and the average daily maximum readings indicate that it was warmer in Gate's Pass, a narrow rocky canyon, than at the other stations. They further indicate the obvious definite daily and seasonal relationship between the ambient and the tree-hole temperatures.

Table 5

Average minimum saguaro tree-hole temperatures, and ambient temperatures at the primary study site in the Tucson Mountains during the three manual observations: June 9 to 11, June 21 to 23 and July 15 to 17, 1963. Graphed in Figs. 7 and 8.

Temperature (°C)

	North			South		
Date	Ambient	Difference	Tree-hole	Ambient	Difference	Tree-hole
June 9-11	17.75	5.5	23.25	17.75	5.85	23.6
Difference	0.75	—	2.25	0.5	—	1.65
June 21-23	18.5	7.0	25.5	18.25	7.0	25.25
Difference	7.0	—	5.1	7.25	—	6.25
July 15-17	25.5	5.1	30.6	25.5	6.0	31.5

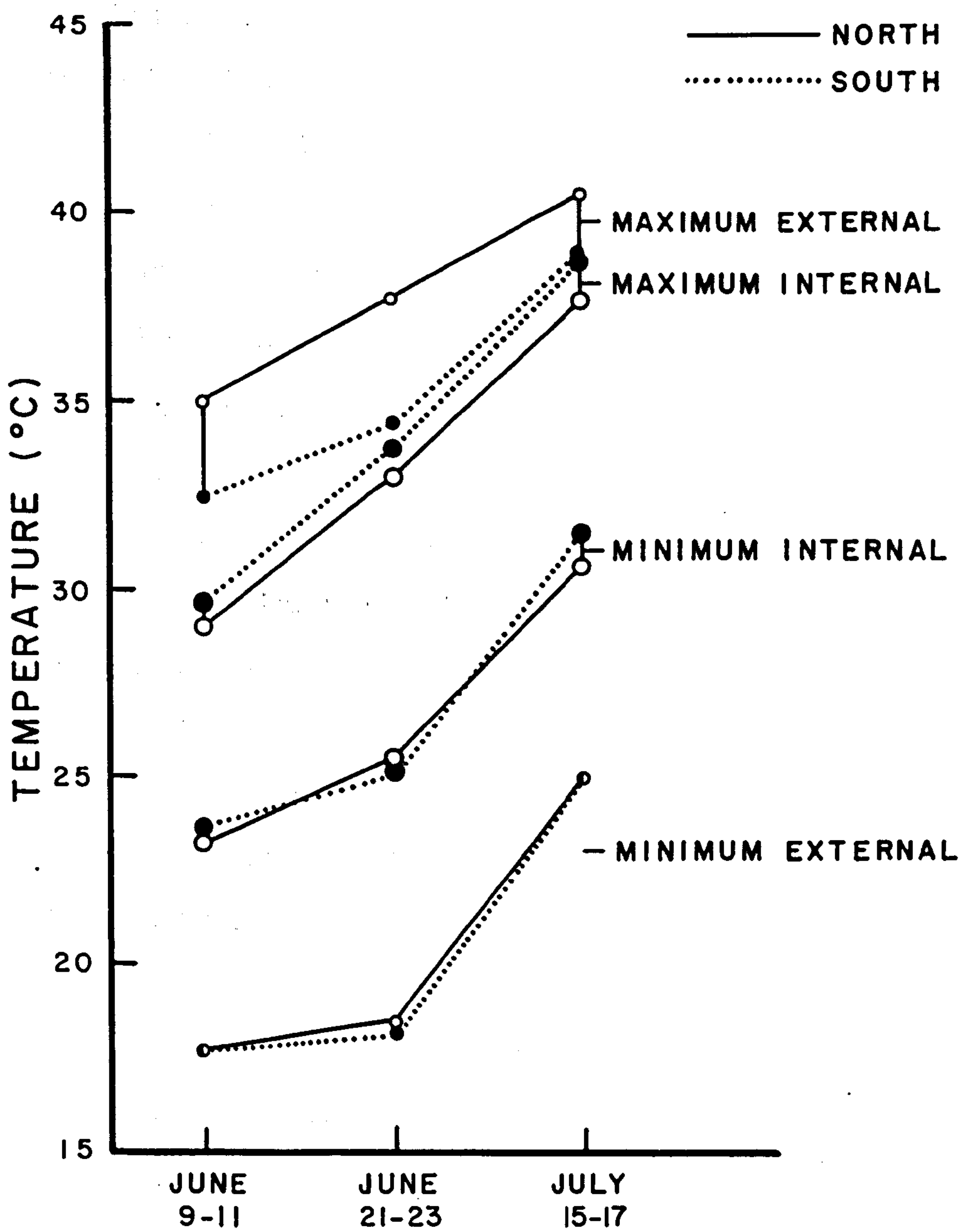

Fig. 8. A comparison of ambient to ambient and tree-hole to tree-hole average maximum and minimum temperatures for the summer of 1963; north-facing and south-facing saguaro tree-holes. Data in Table 5.

The internal air temperatures of both north-facing and south-facing tree-holes under maximum-minimum temperature observation also reached their maxima of over 105°F once earlier during the summer. These occurred on days (north-July 14 and south-July 18) a few degrees cooler than the official high (July 23).

It is noted that the difference between the average maxima of the north-facing and south-facing tree-holes is negligible (north, 102.8°F = 39.2°C; south, 102.7°F = 39.3°C). Each is significantly lower than the ambient temperature, being 5.0°F (2.8°C) below the average in Gate's Pass, 4.3°F (2.35°C) below that of the University of Arizona weather station, and 0.72°F (0.4°C) below the Tucson Airport. This illustrates the well known need for data from the specific study area as distinct from that of the nearest official weather bureau station.

During the warmest period of the summer, July 14 to July 28, the south ambient temperature reached its peak near noon, and the north ambient reached its maximum at ca. 4:00 pm. Both achieved their minima just before sunrise. As expected, the south ambient rises more quickly during the day and the north ambient drops at a slower rate at night.

The temperature of the south ambient is due to the canyon-effect and direct insolation. The temperature of the north-facing ambient is due to the canyon-effect alone. The canyon-effect is back-radiation from the surrounding walls. The rising sun reflects off the north-facing slopes, warming the air around the south-facing tree-hole and shining directly on it. The setting sun reflects off south-facing slopes and the accumulated heat is radiated toward the north-facing saguaro tree-hole, warming the air.

The crossover-time for the north and south ambient is constant at 7:00 am and pm. The crossover-time referred to here and at other places herein is that period when the upswing of one temperature under observation and the downward movement of another temperature pass a common point. After the evening crossover of the outside ambient and the internal tree-hole temperatures, both hole temperatures reach their peak. Then they drop in similar fashion until sunrise when the south-facing hole rises more rapidly than the north. Here there is no real crossover for the north and south tree-holes, the south being consistently warmer.

A lag of approximately three hours exists between the maximum north ambient temperature and the maximum north-facing tree-hole temperature. And a lag of over five hours occurs between the south ambient and the south tree-hole maximum. This period also shows, in fact, the progressive decrease in the difference between ambient and tree-hole maximum temperatures as a result of the increasingly warmer weather. And again this change is not observed for the minimum temperatures.

During the warmest period of the summer (July 14 to July 28), saguaro tissue temperatures were also recorded on July 15-July 17. The close correlation of tree-hole temperatures with the temperature of the saguaro tissue and the ambient temperature is again obvious in this work.

In this hottest summer period the ambient temperature approached or exceeded 43.0°C on six occasions while the corresponding tree-hole temperatures approached or exceeded 41.0°C only three times. This further indicates that the greatest effectiveness of the tree-hole in modifying the summer microclimate lies in the upper thermal range, ca. 40-45°C ambient.

It rained on July 10, 1963 from 1:30 pm to 5:30 pm, with the greatest intensity about 3:00 pm. Total precipitation measured at Tucson International Airport was 0.14 inches. The sub-epidermal and cortex temperatures were already falling before the rain started, as a result of the heavy cloud cover and the generally lower ambient temperature (33.0°C, a drop of 6-8° from the previous day). The ribs and pith temperatures followed a modified curve falling off about one hour before the usual time (Fig. 9, Table 6).

The irregular temperature pattern of the saguaro tissue (see Fig. 9, Table 6) in this case is linked directly to the rain. The details of the mechanisms involved in the control of the temperature curves shown are not fully understood.

The drop of 9.0°C in less than four hours was not accompanied by a similar reduction in the tree-hole temperature. Both the north and south tree-hole temperatures increased after the initiation of the rain, indicating an acceptance of internal heat radiation from the plant, which is the same phenomenon that warms the hole after sunset. The south hole had a slightly lower temperature during the rain (see Fig. 10, Table 6). Most likely this was due to the winds which carried the rain from the southwest.

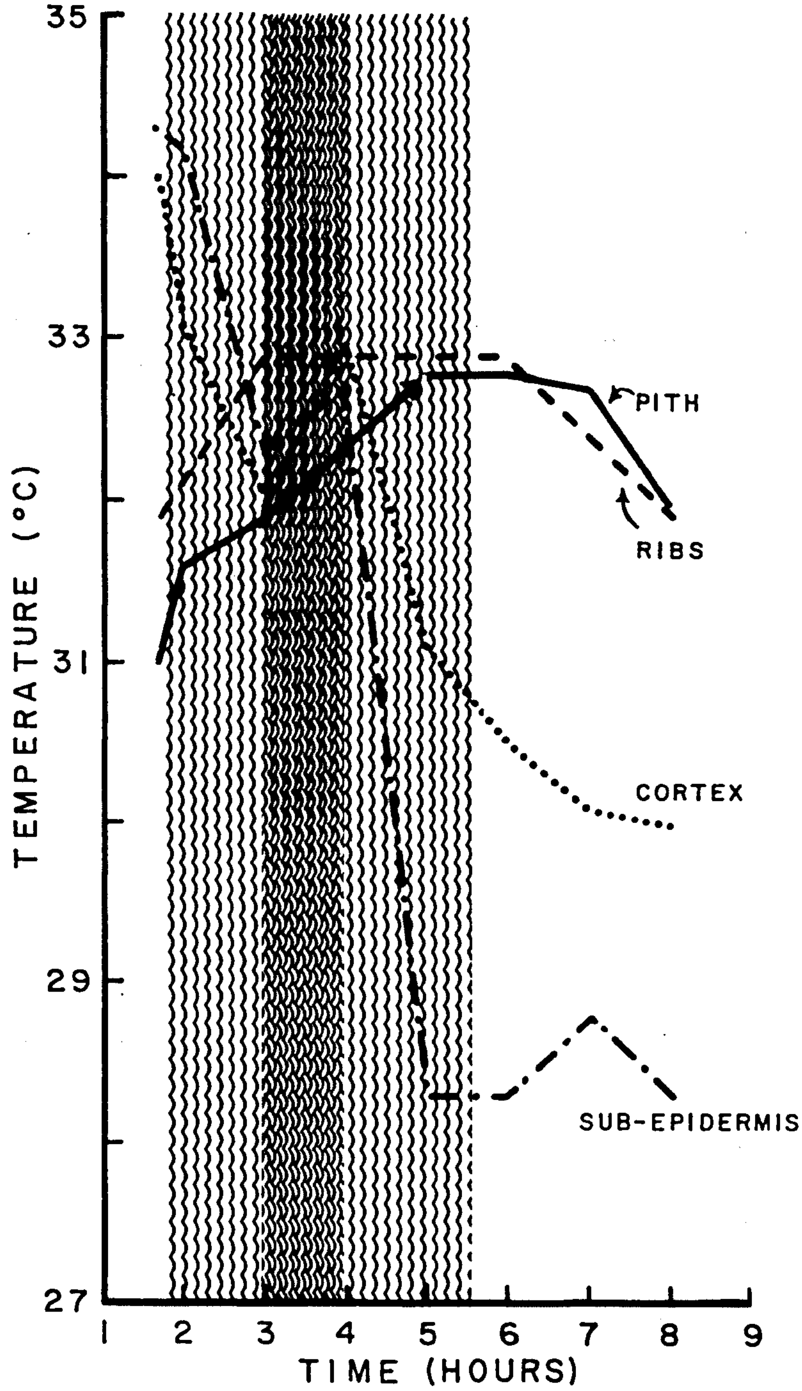

Fig. 9. Hourly temperatures of saguaro tissue between 1:30 pm and 8:00 pm on July 10, 1963. Rainfall during this period (0.14 inch, Tucson Airport) is indicated by shading. Period of maximum intensity is in darker shading. There is no reading between points indicated by arrow (pith). See Table 6 and p. 4.

Table 6

Eight hour recordings of north-facing and south-facing saguaro tree-holes, north and south ambient, humidity and saguaro tissue; at the primary study site in the Tucson Mountains during a 0.14 inch (Tucson Airport) rain on July 10, 1963. Data recorded manually and graphed in Figs. 9, 10 and 12.

Date	Temperature (°C)								Humidity (%)			
and	Tree-hole		Ambient		Tissue				Tree-hole		Ambient	Weather
Time	North	South	North	South	Sub-ep[1]	Cortex	Ribs	Pith	North	South	North	Shelter
1963 7/10												
1:40 pm	31.0	32.8	33.0	33.0	34.3	34.0	31.9	31.0	48.0	28.0	28.0	37.8
2	30.2	33.0	31.3	31.4	34.2	33.1	32.1	31.6	47.0	28.0	29.0	37.6
3	31.9	32.1	26.0	25.9	32.3	32.0	32.9	31.9	47.0	30.0	36.0	70.0
4	31.5	32.0	23.8	23.0	32.7	33.0	32.9		47.6	30.0	55.0	66.5
5	31.3	31.8	22.3	22.0	28.3	31.1	32.9	32.8	51.0	35.0	83.0	77.0
6	31.0	31.2	24.0	23.5	28.3	30.5	32.9	32.8	52.8	32.5	65.5	60.0
7	30.1	30.9	24.0	23.9	28.8	30.1	32.4	32.7	54.0	35.0	80.0	70.0
8	30.0	30.0	23.5	23.2	28.3	30.0	31.9	32.0	56.0	35.0	79.5	70.0

[1]Sub-epidermis

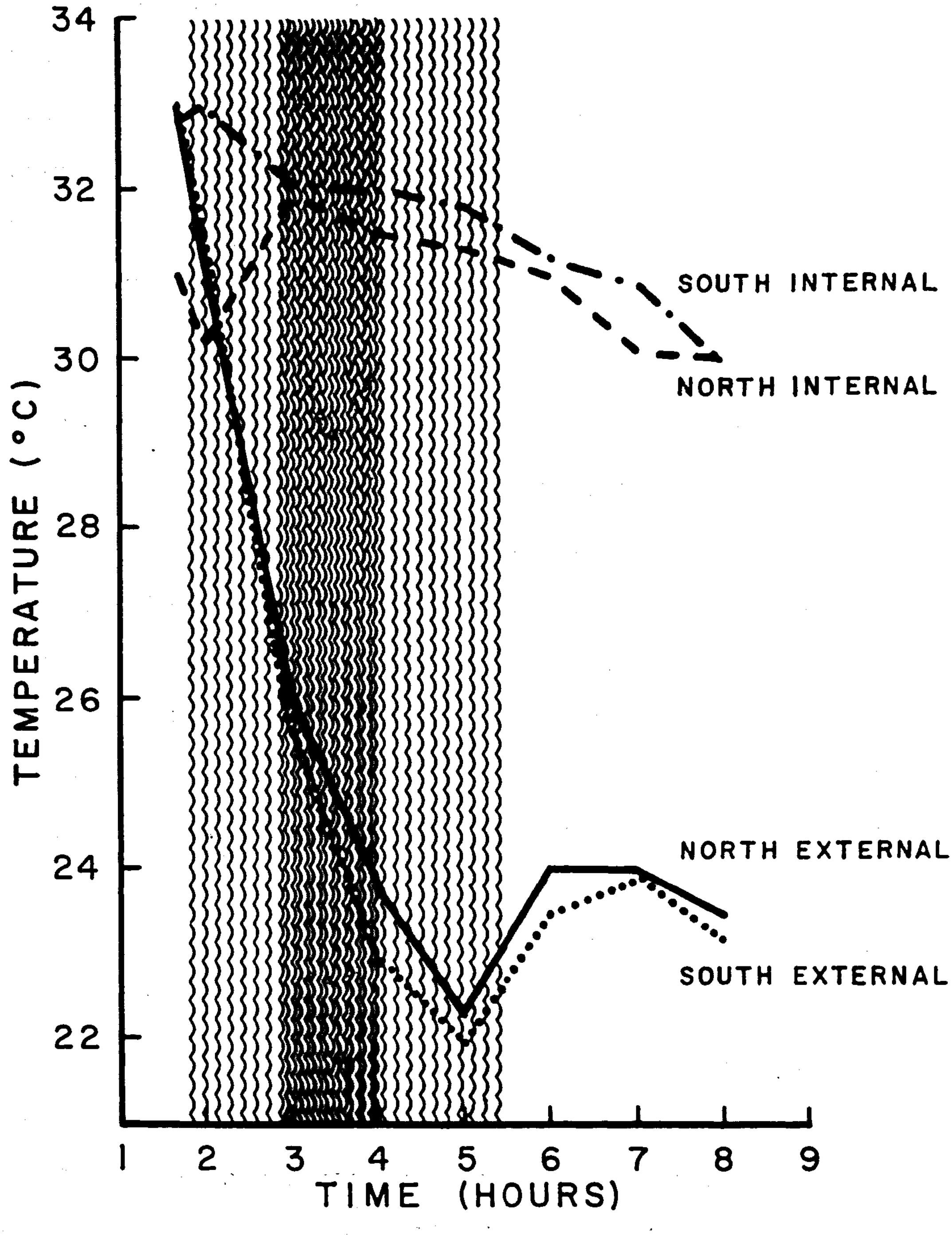

Fig. 10. Hourly temperatures of air outside and inside a south-facing and a north-facing saguaro tree-hole between 1:30 pm and 8:00 pm, July 10, 1963. See Table 6 and Fig. 9.

This shows that the tree-hole temperatures are controlled primarily by the plant itself and only indirectly by the air temperature and wind currents. The lack of a sudden drop in tree-hole temperature, as found in the air, relegates the role of wind and air currents to secondary importance as the direct causal factor of tree-hole temperature variation.

Humidity

Variation and modification of humidity within the saguaro tree-hole was recorded from July 15 to July 17 at the primary study area. Readings were obtained for the north-facing and south-facing tree-holes, and also from outside the north-facing tree-hole. During this period the outside or ambient humidity was consistently lower, as expected. Both this and the south internal humidity were quite steady throughout the observation.

The north internal humidity showed the greatest fluctuation hourly. Of the three humidities, it gave the best indication of a nocturnal maximum. During both nocturnal periods it reached a high point between 4:00 and 6:00 am. The ambient and south internal also reached their highest levels during this time. However, neither was as great as the north internal humidity.

The period of minimum humidity fell in the early afternoon. The minimum appears to be more variable than the maximum from day to day (see Fig. 11, Table 7).

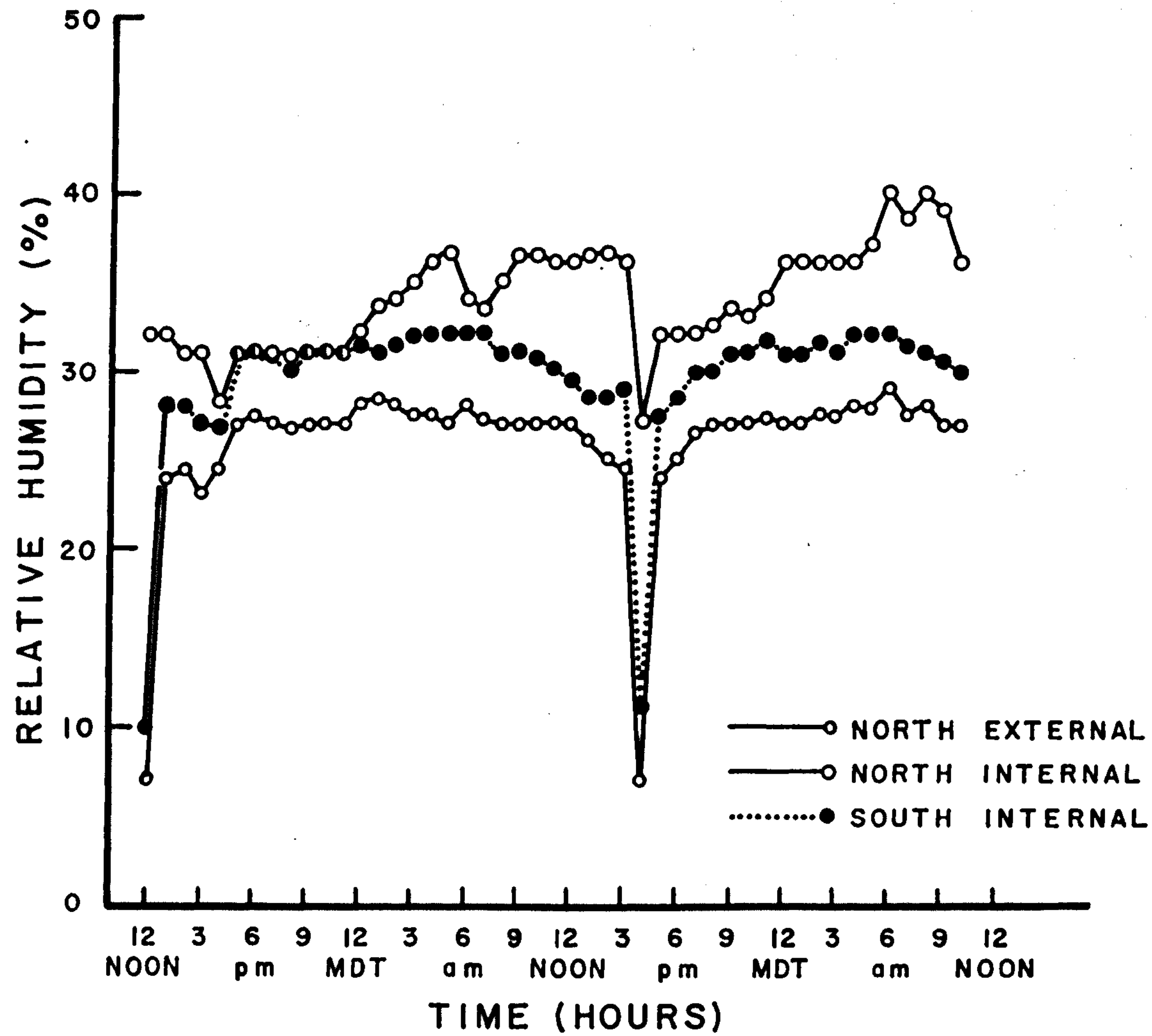

Fig. 11. Hourly humidity readings in a north-facing and a south-facing saguaro tree-hole, and outside of the north-facing tree-hole, between noon July 15 and noon July 17, 1963. Data in Table 7.

Table 7

Forty-seven hour humidity recordings from north-facing and south-facing saguaro tree-holes and north ambient humidity, at the primary study site in Tucson Mountains. Data recorded manually from July 15 to July 17, 1963. Graphed in Fig. 11.

Date and Time	Humidity (%) Tree-hole North	South	Ambient North
1963 7/15			
12 noon	32.0	10.0	7.0
1 pm	32.0	28.0	24.0
2	31.0	28.0	24.5
3	31.0	27.0	23.0
4	28.1	37.0	34.8
5	31.0	31.0	27.0
6	31.0	31.0	27.2
7	31.0	30.9	27.0
8	30.8	30.0	26.8
9	31.0	31.0	27.0
10	31.0	31.0	27.0
11	31.0	31.0	27.0
12 mid	32.0	31.2	28.0
7/16			
1 am	33.5	31.0	28.2
2	34.0	31.5	28.0
3	35.0	32.0	27.5

Table 7 (continued)

Date and Time	Humidity (%) Tree-hole North	Humidity (%) Tree-hole South	Humidity (%) Ambient North
1963 7/16			
4 am	36.0	32.0	27.5
5	36.5	32.0	27.0
6	34.0	32.1	28.0
7	33.5	32.0	27.2
8	35.0	31.0	27.0
9	36.5	31.0	27.0
10	36.5	30.9	27.0
11	36.0	30.0	27.0
12 noon	36.0	29.5	27.0
1 pm	36.0	28.5	26.0
2	36.5	28.5	25.0
3	36.0	29.0	24.5
4	27.0	11.0	7.0
5	32.0	27.5	24.0
6	32.0	28.5	25.0
7	32.0	30.0	26.5
8	32.5	30.0	27.0
9	33.5	31.0	27.0
10	33.0	31.0	27.0
11	34.0	31.5	27.2
12 mid	36.0	31.0	27.0

Table 7 (continued)

Date and Time	Humidity (%) Tree-hole North	Tree-hole South	Ambient North
1963 7/17 1 am	36.0	31.0	27.0
2	36.0	31.5	27.5
3	36.0	31.0	27.5
4	36.0	32.0	28.0
5	37.0	32.0	28.0
6	40.0	32.0	29.0
7	38.5	31.1	27.5
8	40.0	31.0	28.0
9	39.0	30.5	27.0
10	36.0	30.0	27.0

The data indicate that the level of humidity in empty saguaro tree-holes is closely related to, if not directly dependent on, the ambient humidity. The fact that there is no crossover between the internal and external humidities is indicative of this essential dependency of the internal tree-hole humidity on the external humidity.

The tree-hole may function as a trap which allows a higher humidity to develop; for the tree-hole does create a microclimate which has a relative humidity 4 to 10% higher than that outside it. This difference fluctuates with and slightly above, the highly variable ambient. Moreover, the internal humidity lags about one hour behind the ambient. This is a further indication that some modification of the humidity is being realized within the tree-hole.

A slightly higher level of internal relative humidity coupled with internal (tree-hole) temperature may create a more favorable situation for overall body moisture conservation. This is a factor which could be of importance to the small animals present.

No humidities were taken with animals in the tree-holes, a matter for future inspection. It is assumed that with one or more large animals (e.g., birds) present, the trap-effect mentioned above would create an even more favorable humidity situation for the tree-hole inhabitants.

During the rain of July 10, 1963, the humidity in both the north-facing and south-facing tree-holes as well as that outside the north hole and in the weather station were recorded. There was, in general, an increase in the relative humidity within the tree-holes following the increase in the ambient due to the rain.

The north tree-hole humidity was already 16% higher than that in the south tree-hole (40% vs. 24%) at the start of the precipitation. It maintained this respectable separation throughout the observation, ending at 48% and 31%. The lack of great increase in the humidity over a long period of hours indicates that what little water entered the hole during the period of observation did not increase the internal humidity. The increase of 7% to 8% of the tree-hole humidity that followed was, most likely, due to the circulation of air. Since in comparison this was small, it again suggests the minor importance of air circulation in controlling the humidity component of the micro-environment of the saguaro tree-hole.

The ambient humidity showed a rapid fluctuation (37.5% to 70%) in the first hour of the rain. During this period the relative humidity in the weather station rose from 32% to 79% in two hours. Both were maintained at a level higher than in the tree-holes. All except the north internal showed a dip in humidity around sunset, indicating the rapid drying effect of sun energy on desert air with momentarily high moisture content. This trend was halted by the setting of the sun and the associated gradual loss of heat energy (see Fig. 12, Table 6).

Water

Not all saguaro tree-holes collect water. Those having a protruding lower lip, or that lie in a recession in the arm or trunk, appear to have the highest probability of water content. Once the water is in the hole, several natural conditions determine how long the water will remain (see Krizman, 1964).

Holes located near the center of the tree have a generally lower temperature and therefore a lower evaporation rate. The internal configuration is important. Holes with some kind of constriction allow a higher humidity to develop; this structure encourages little circulation of air. The foreign material inside the tree-hole affects the available evaporational surface area. The ribbed surface of the plant is an effective feature which helps conserve rain water by channeling it past the tree-hole during surface run off.

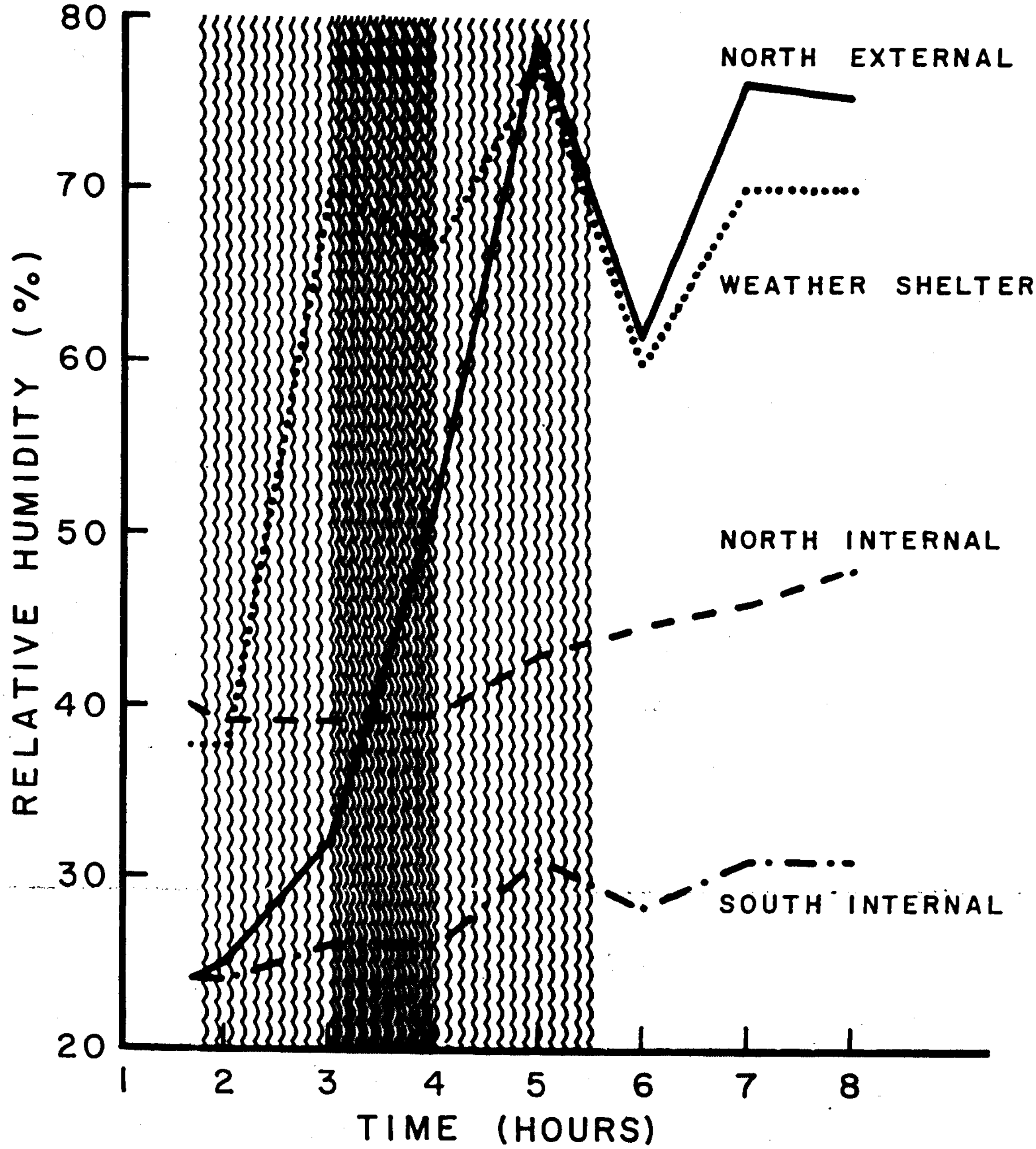

Fig. 12. Hourly humidity readings inside and outside a north-facing saguaro tree-hole, inside a south-facing tree-hole, and inside an adjacent weather shelter, from 1:30 pm to 8:00 pm, July 10, 1963. Rainfall during this period totaled 0.14 inch(Tucson Airport). See Fig. 10 and Table 6.

One or more of these factors in connection with relative humidity and amount of rainfall determine how much and how long water will be found in saguaro tree-holes.

From observations in the field, it appears that ordinarily the water of the first rain functions to allow subsequent rain water to remain longer. The water causes a swelling of the callus tissue, aiding the prevention of leakage. There does not appear to be any direct or indirect transfer of water from the plant into the hole or vice-versa.

The cardinal direction of the hole does not appear to play an important role in the evaporation of the contained water; the importance of wind-direction on the accumulation of water seems, indeed, considerable. Also, a stronger wind will result in a flatter trajectory of the rain thereby making it more likely for rain to blow into a tree-hole. The wind in the form of air turbulence may also play an important role in the evaporation of tree-hole water.

Evaporation

As reported above, saguaro tree-holes can collect and store rain water. Many kinds of birds are known to use this source for drinking (see Krizman, 1964). However, many of these tiny reservoirs go unused by the animals of the desert. It is even possible that many birds do not take full advantage of these life-saving holes.

One such hole was found on the western slope of the Tucson Mountains. This area supports moderately heavy bird populations; the area was without surface water during early summer. The tree-hole was located on June 15, 1963 and contained 3.75 inches of water. This was

51 days after the last measurable rain (0.32 inches at Tucson Airport), and in the 78 days preceding this there had been only 0.38 inches of recorded precipitation. It took only 10 days after the original measurement (June 15) for all the water in the hole to disappear (see Fig. 13, Table 8). The only disturbance of this hole by the author was for the four readings taken to determine the depth of the water. The disturbance from these readings would be quite similar, mechanically, to a bird drinking. Thus the rapid evaporation of the water after disturbance by the observer may indicate that the hole was not being used previously for drinking.

The holes that do retain water for an extended period are relatively scarce. If they are used for drinking, and this appears certain, two further possibilities exist. One, the finding and subsequent use of tree-hole water by birds may be based entirely on chance, or two, the birds know of these holes and protect them from intruders. This could be a territorial behavior, which might be interpreted as a kind of avaian water conservation program. The latter hypothesis is obviously the more intriguing.

The holes which retain water for extended periods of time may do this by forming a seal in the tree-hole at the water-air interface. Water taken from tree-holes was used in laboratory experiments. It was placed in graduated cylinders and formed a filmy surface layer when left undisturbed.

Table 8

Field evaporation from a saguaro tree-hole on the western bajada of the Tucson Mountains, under observation from June 15 to June 25, 1963. Graphed in Fig. 13.

Date 1963	Depth (inches)
6/15	3.75
6/18	2.50
6/21	1.35
6/23	0.75
6/25	0.00

The seal may originally start as small pieces of debris floating on the surface after a rain. Suspended substances (oils, for example) could contribute to the seal formation. Larger pieces of callus, seeds and animal refuse (e.g., feathers, feces) may be contributing constituents. The larger pieces are in time brought together by evaporation that lowers the water level. Also the form of the tree-hole, which usually tapers toward the bottom, could be important. As the water level recedes, more debris is picked up from the sides while some is left behind. In this way a compact seal may be formed. Such a seal would be self-generating and progressively more viscid as evaporation proceeds.

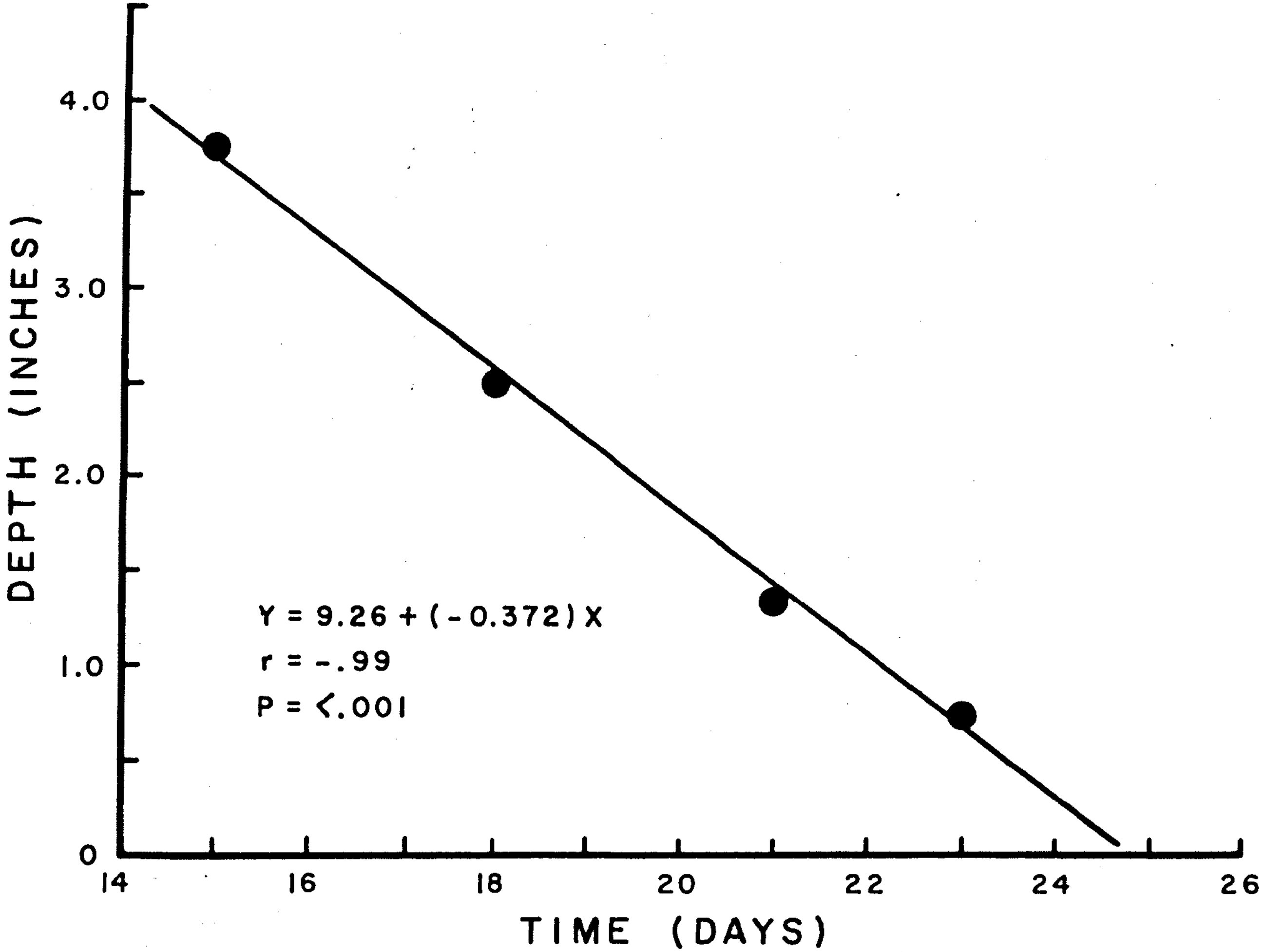

Fig. 13. Regression of depth of tree-hole water on time, for a saguaro tree-hole under field observation during June, 1963. Data in Table 8.

Light

The construction of the saguaro tree-hole makes it one of the best and most readily accessable escapes in the desert from the rays of the sun, providing it can be reached. Light intensity decreases with the depth of the tree-hole. Also it strikes the hole in minimal quantity during summer. In all cases the decreasing angle of the sun (summer to winter) results in a lower intensity of light at the openings of north-facing tree-holes and an increase in intensity at the south-facing ones. The seasonally changing position of the sun accounts for the seasonal variability in the light curve in the tree-holes examined.

North-facing and south-facing tree-holes at equal heights (ca. 12 feet) and depths (ca. 10 inches) were used. Also the times of study were widely spaced to observe the nature of expected seasonal differences--July 2, September 20 and December 18, 1963.

<u>Outside The Tree-hole</u>.--Measurements for the outside of the holes were obtained on the latter two dates. A maximum reading for the south-facing tree-hole of 9,200 foot-candles (f.c.) was recorded in September. In December the comparable reading was well off the scale of 10,000 f.c. This was an increase of over 1,000 foot-candles for the period. On the north side of the saguaro stem, at the position of the north-facing tree-hole, the seasonal change was slight--1,300 f.c. in September to 1,200 f.c. in December (Fig. 14, Table 9).

This respectable seasonal difference in lighting on the north and south sides of saguaro stems is directly related to the progressively shifting position of the sun toward the south and the accompanying winter decrease of its angle of inclination.

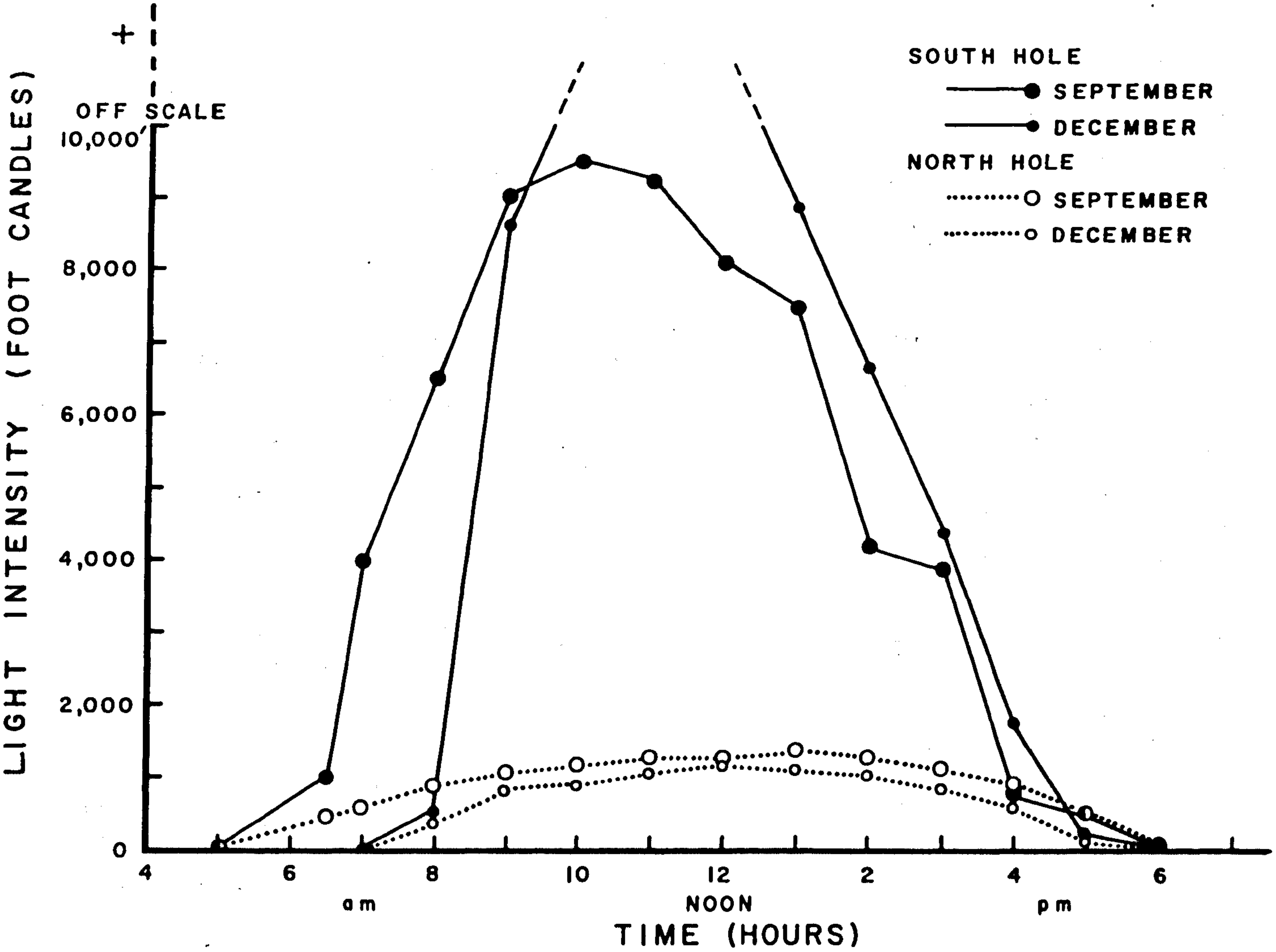

Fig. 14. Light intensities received near the openings(outside) of a north-facing and a south-facing saguaro tree-hole on September 30 and December 18, 1963. Data in Table 9.

Table 9

Hourly recordings of light intensity received at the opening of a north-facing and a south-facing saguaro tree-hole on the eastern bajada of the Tucson Mountains. Data recorded manually on September 30 and December 18, 1963. Graphed in Fig. 14.

Intensity (foot-candles)

Time	September 30		December 18	
	North	South	North	South
4 am	0	0	0	0
5	0	0	0	0
6			0	0
6:30	500	1000		
7	600	4000	5	3
8	900	6500	400	550
9	1100	9000	845	8600
10	1200	9500	930	10000
11	1300	9200	1100	10000
12	1300	8100	1200	10000
1 pm	1400	7500	1150	8850
2	1300	4200	1075	6650
3	1150	3900	890	4400
4	920	850	640	1800
5	550	550	160	220
6	34	54	0	0
7	0	0	0	0
8	0	0	0	0

Only during the early hours after sunrise does winter sunshine fall on the north side of the plant.

In The Opening Of The Tree-hole.—In July, the south hole (685 f.c.) received only slightly more light than the north (460 f.c.). However, in September 48% of the available light entered the south-facing tree-hole and 19% entered the north-facing hole. This represented a relatively small decrease in the north hole (460 f.c. to 250 f.c.) and a large increase in the south (from 685 f.c. to 4,600 f.c.) for September.

In December, the maximum light intensity in the opening of the south-facing tree-hole registered 8,650 f.c. In the north hole opening it was 650 f.c., which was 54% of that outside (Fig. 15, Table 10). The higher maximum light intensity reached during the winter in the south hole is due to the winter sun angle being the lowest for the year.

The Middle Of The Tree-hole.—Over the seasons, the middle of the hole exhibits greater uniformity in light intensity than does the opening. While the intensity of light entering varies between north and south tree-holes, the percentage of the light that reaches the middle of either hole is more uniform, it is 1% to 5% of the light falling into the opening with one exception (September). In July 5% of the light entering the north-facing tree-hole reached the middle and 2% of that entering reached the middle of the south-facing tree-hole. During this month, a maximum of 21.9 f.c. reached the center of the north-facing tree-hole at 7:00 am. The maximum for the south-facing tree-hole (15.0 f.c.) was reached at noon. The difference in these maximum intensities is related to the position of the early July sun at the times indicated.

Table 10

Hourly recordings of light intensity received inside the opening of a north-facing and a south-facing saguaro tree-hole on the eastern bajada of the Tucson Mountains. Data recorded manually on July 2, September 30 and December 18, 1963. Graphed in Fig. 15.

Intensity (foot-candles)

Time	July 2		September 30		December 18	
	North	South	North	South	North	South
4 am	0	0	0	0	0	0
5	20	3	0	0	0	0
6	230	140			0	0
6:30			100	1000		
7	460	340	130	1200	0.5	2
8	370	380	150	2000	150	370
9	350	685	160	3500	285	5800
10	250	550	170	4600	370	8300
11	160	380	200	2500	450	8650
12	348	350	250	1000	585	7400
1 pm	360	470	250	1000	500	4800
2	320	480	180	800	650	2400
3	250	370	170	560	550	1200
4	280	300	155	350	410	480
5	270	150	175	320	92	110
6	50	50	12	25	0	0
7	6.5	1	0	0	0	0
8	0	0	0	0	0	0

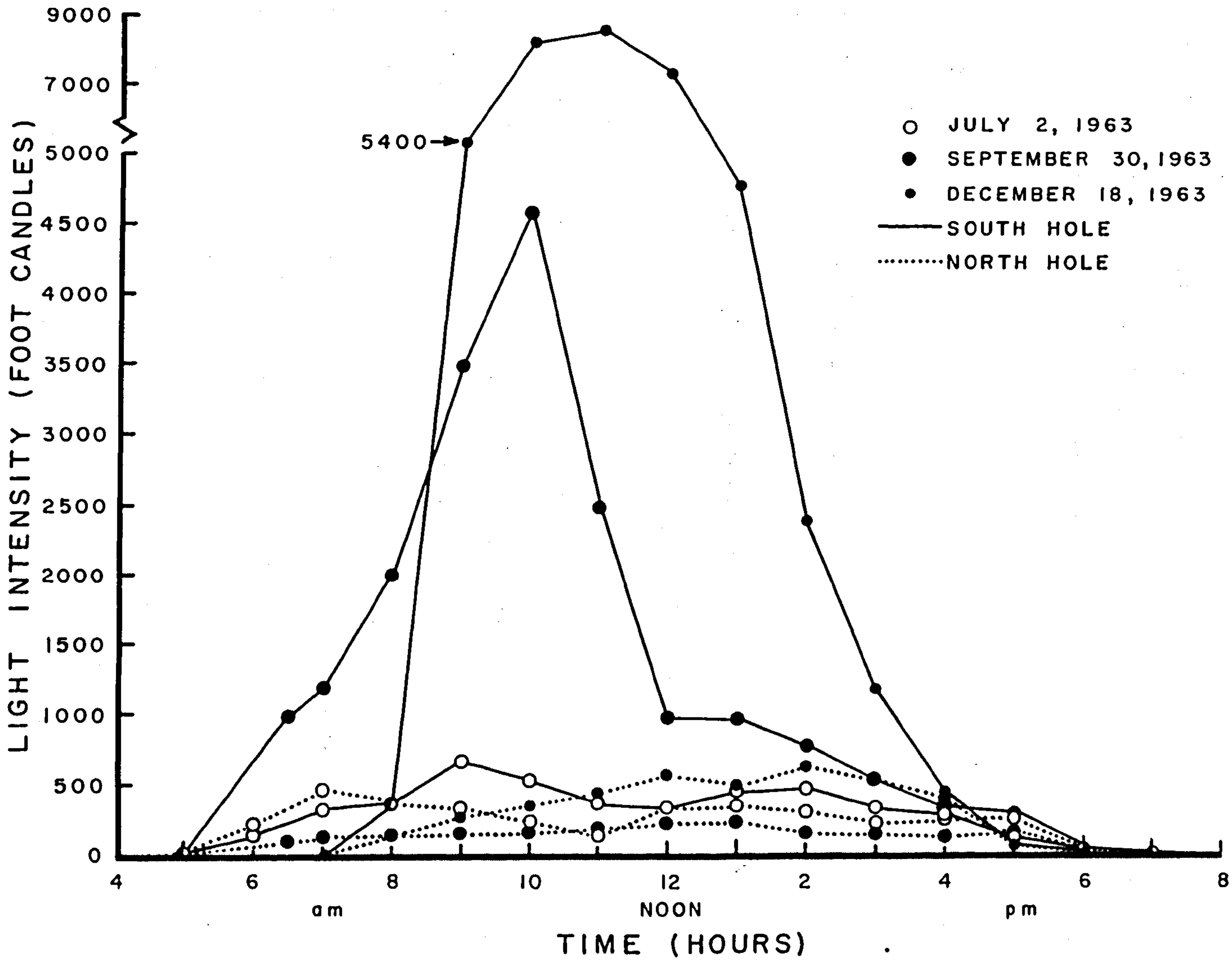

Fig. 15. Light intensities received inside the openings of saguaro tree-holes on July 2, September 30, and December 18, 1963. Data in Table 10.

By September, the value for the south-facing tree-hole had increased ten-fold (to 150 f.c.) and in the north hole by only one-third (from 21 to 28 f.c.). The ten-fold increase in the light intensity of the south-facing tree-hole did not affect the percentage of light that reached as far as the middle of the hole; the amount of light increased only from 2% to 3%. The one exception to this generalization was in the middle of the north-facing tree-hole during September. Here the light reaching the middle was higher, on the order of 10%. Nevertheless, it was still only 2% of the light outside the saguaro at that time.

In December, the light intensity dropped to 10.8 f.c. in the north-facing opening and to 60.0 f.c. in the south-facing one. This drop still was 2% of the light at the mouth for the north, and just under 1% (0.7%) for the south (Fig. 16, Table 11). These percentages are similar to those recorded in July. There is a shift from direct light (July) to reflected light (December) in the lower parts of the tree-hole. Again this is due to the decreasing angle of the sunlight entering the hole. It is interesting to note that when the sun is in an intermediate position (September), the combination of the two angles (direct and reflected light) provides a much higher incidence of light reaching the middle than does either extreme individually.

<u>At Bottom Of Tree-hole</u>.—There is relatively little seasonal variation at the bottom. The readings for the south hole were 12, 16 and 12 f.c. for the three months studied. Only one reading was available for the bottom of the north hole and this was of 4 foot-candles in July (see Fig. 17, Table 12). After this the opening was closed by necrotic tissue (black grume or "goo").

Table 11

Hourly recordings of light intensity received in the middle of a north-facing and a south-facing saguaro tree-hole on the eastern bajada of the Tucson Mountains. Data recorded manually on July 2, September 30, and December 18, 1963. Graphed in Fig. 16.

Intensity (foot-candles)

Time	July 2		September 30		December 18	
	North	South	North	South	North	South
4 am	0	0	0	0	0	0
5	1.0	1.2	0	0	0	0
6	19.5	3.2			0	0
6:30			5	5		
7	21.9	4.0	5	9	0	0
8	13.0	6.5	5	13	2.5	4.5
9	12.5	9.0	28	85	6.5	52.5
10	13.3	9.5	13	130	5.5	54
11	12.5	9.5	13	150	10.8	57
12	10.5	15.0	13	75	10	60
1 pm	13.3	12.0	15	25	7.5	22.5
2	14.5	11.0	16	19	7.5	17
3	8.9	12.6	15	6	4	9.5
4	9.2	10.0	6	2	5	6.0
5	11.5	6.5	5	4	1	1.0
6	9.0	3.9	0	1	0	0
7	0.5	0	0	0	0	0
8	0	0	0	0	0	0

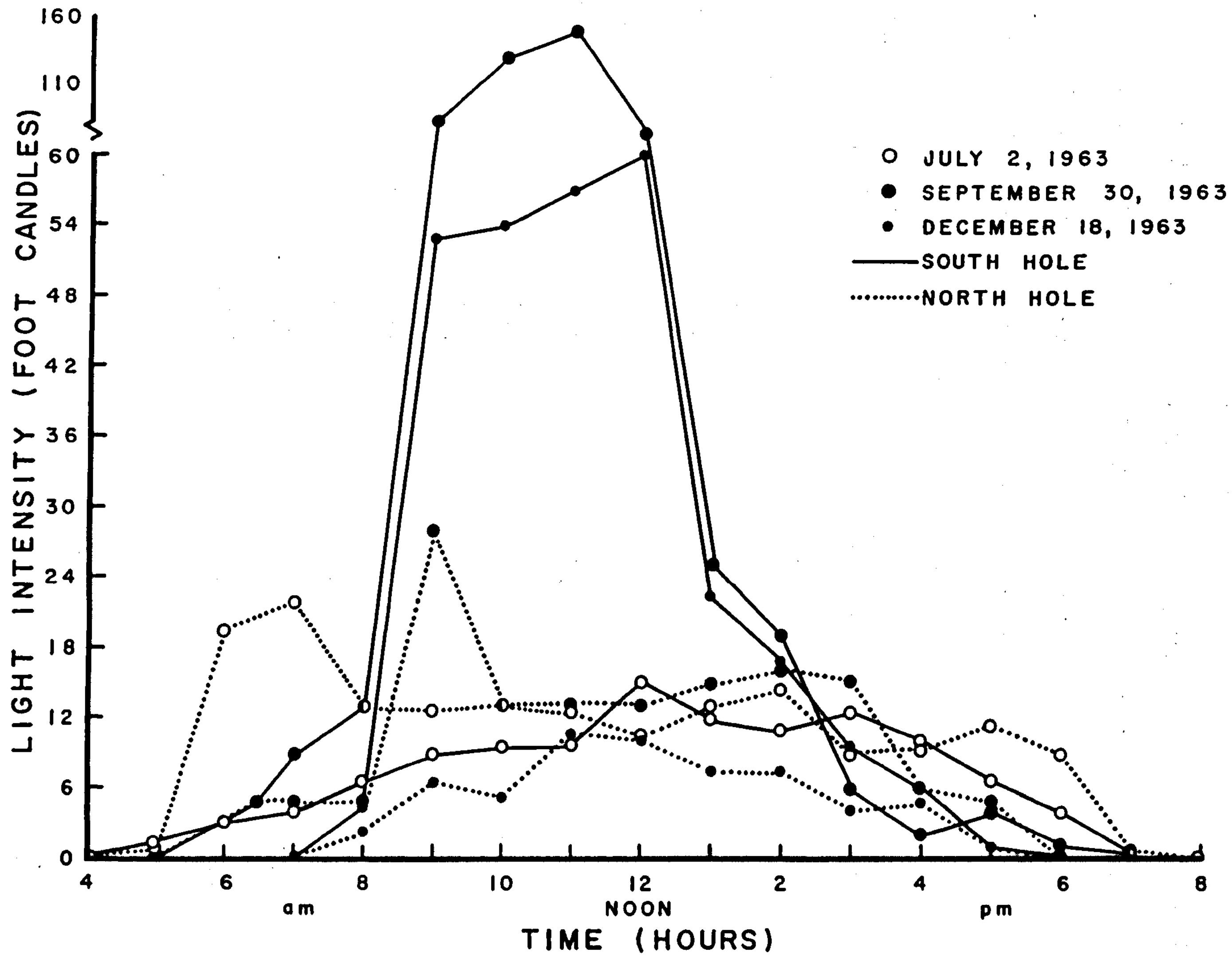

Fig. 16. Light intensities at the middle of saguaro tree-holes on July 2, September 30, and December 18, 1963. Data in Table 11.

Table 12

Hourly recordings of light intensity received at the bottom of a north-facing tree-hole on July 2, and at the bottom of a south-facing tree-hole on July 2, September 30, and December 18, 1963, on the eastern bajada of the Tucson Mountains. Graphed in Fig. 17.

Time	Intensity (foot-candles)			
	July 2		September 30	December 18
	North	South	South	South
4 am	0	0	0	0
5	1.0	0	0	0
6	5.5	0.8		0
6:30			1.0	
7	7.0	1.0	1.0	0
8	3.6	1.0	1.0	10
9	3.0	1.4	8.0	12.0
10	3.0	1.0	16.0	9.2
11	3.3	1.0	11.0	10.0
12	4.0	2.0	5.0	9.0
1 pm	4.0	12.0	2.0	5.5
2	4.0	1.5	1.0	2.0
3	1.1	1.0	1.0	1.0
4	2.0	1.8	0	1.0
5	3.4	3.5	1.0	0
6	2.0	0	0	0
7	0.5	0	0	0
8	0	0	0	0

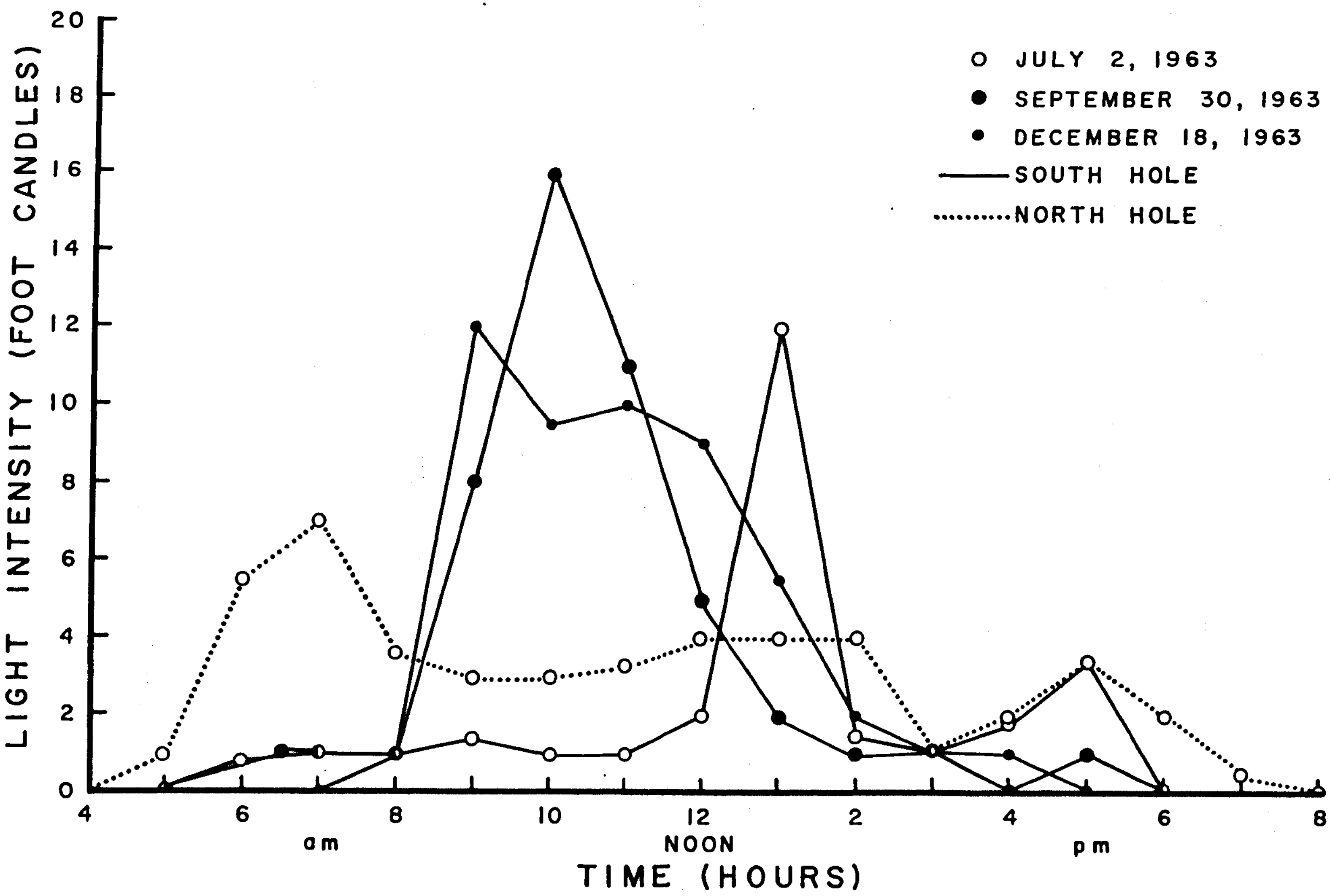

Fig. 17. Light intensities received at the bottom of saguaro tree-holes on July 2, September 30, and December 18, 1963. Data in Table 12.

Only 0.1% to 0.2% of the available light outside reaches the bottom of the saguaro tree-hole during any season. It appears that once light reaches the middle of the hole, its chances of getting to the bottom are good. Between 11% and 80% of the light at the middle reached the bottom during the three month period of observation and again these are comparatively small quantities.

The saguaro tree-hole is effective in shielding and "filtering" out over 99% of the solar radiation—at the bottom. Most of this occurs between the opening and the middle of the tree-hole.

INHABITANTS

Vertebrates

The vertebrate inhabitants observed were birds and mammals. No reptiles were observed in the tree-holes, and in the area of study reptiles appear to be infrequent visitors as recorded by others (Howes, 1954; Brandt, 1951).

Birds

Both resident and migrant (= summer resident) birds use the saguaro tree-holes during the summer. The Purple Martin (*Progne subis*) is a common migrant found in the saguaro forest. A pair was observed on June 13, 1963. They flew around a saguaro and entered a southwest facing tree-hole about thirty feet above the ground. When closer observation was attempted, they flew away. It was assumed that these Purple Martins were nesting, since the middle of June is well into their breeding season and extremely late for migration (Bent, 1942).

Another summer resident found in the tree-holes is Whitney's Elf Owl. Bent (1938) records the last eggs of the season of this species as being present in a saguaro tree-hole on June 9. In the present study two separate sightings were made in 1963. On June 14, a pair of Elf Owls, one male and one female, were located in south-facing tree-hole with one chick and one egg. These were all removed from the nest and then returned, with the male protesting vigorously by repeatedly snapping his beak. Two more Elf Owls were observed on July 11, 1963. Their plummage did not indicate that they were juveniles. These birds were banded on their right legs with Fish and Wildlife Department bands #505-26363 and #505-26364. Their sex was not determined. The niche of this nocturnal predator is enhanced by the utilization of saguaro tree-holes. This permits the Elf Owl to utilize the rodent and insect-rich upland desert community in addition to the riparian hardwood community.

The most obvious permanent residents inhabiting the tree-holes are the Gilded Flicker (Colaptes chrysoides) and the Gila Woodpecker (Centurus uropygialis). Both species excavate holes in saguaros for the purpose of nesting. Gilman (1915) states that both prefer the saguaro when available over hardwoods, such as cottonwood or willow. Gila Woodpeckers appeared to be more numerous than flickers in the area studied. However, they are much noisier and more obviously active, which may account for a part of the greater number of observations.

Willard (1912) assumed that the nests were dug during the summer, after nesting, and then allowed to age until the next season before being used. It has been observed by the author and others (see Krizman, 1964) that holes are under construction in February, and evidence of fresh digging was seen in December. The irregularities in the structure of many holes indicates that they are often expanded subsequent to their initial formation. It is not known if the same holes are used repeatedly and if the modifications are made by the new tenants.

The actual construction is carried out by both males and females. The bird holds itself on the lip of the hole by its two zygodactylious toes. It then leans into the hole and drums the saguaro flesh with its beak. After loosening a piece of tissue, it either grasps the piece with its beak or the piece sticks to the side of the beak due to the plant fluids; the bird then brings it to the mouth of the hole. If the chunk is large, ca. ½ inch, it will be flicked over the shoulder and then the bill wiped by brushing back and forth against the top or sides of the hole. This throwing action accounts for many bits and pieces of black, hardened saguaro tissue impaled around many holes. This sign of activity is a useful tool for the observer for it indicates new holes and new hole activity.

While the other birds mentioned here use the saguaro tree-hole, it is in the order Piciformes that its usefulness is most easily observed. In this study, the most frequent diurnal occupants of the diurnally active birds were the woodpeckers. Occupancy during the summer was between the hours of 10:00 am and 2:00 pm, the hours of highest sun intensity. This indicates that the holes were possibly being used to avoid the intense rays of the sun. In one case, June 15, 1963, an adult Gilded Flicker was observed in a tree-hole by means of a flashlight and mirror. She was pressed tightly against the bottom of the hole and could not be moved, even by probing with a pointed object. The temperature inside the hole was from $5.0^{\circ}C$ to $9.0^{\circ}C$ cooler than that of the ambient. The position of the bird is an example of presenting maximum surface area of a warm body against maximum surface of a cool body in an attempt to dissipate heat. Even if the bird was only protecting her eggs, the location and attitude of her body give good illustration to the point.

Another resident bird which increases the range of its habitat niche by using the saguaro tree-hole is the Screech Owl (Otus asio). On June 8, 1963, a male and a female, both immature, were taken by hand from the same saguaro tree-hole. These specimens were deposited in the University of Arizona collection. The diet of this bird includes lizards, small mammals and insects. Diurnal occupancy of the saguaro tree-hole allows screech owls to utilize effectively a large part of the desert environment which would otherwise be unavailable to them.

Other local residents make use of saguaro tree-holes. The House Finch or Linnet (Corpodacus mexicanus) normally builds a compact nest in a bush, tree or low cactus. In accord with its normal nesting pattern, the Linnet using a tree-hole will first fill the hole with grass and twigs and build its nest on top of this pile. This compromises the natural advantages of hole-nesting; namely, temperature modification, concealment and physical protection. It clearly indicates, of course, that the Linnet has not evolved toward the adaptive use of the tree-hole environment, nor has very wide lability for behavioral modifications relevant to nesting.

The Starling (Sturnus vulgaris), on the other hand, has quickly learned to take advantage of the saguaro tree-hole. This rapidly adapting bird introduced in the United States in 1880, now can be found nesting in the saguaro. On July 23, 1963, a starling was observed carrying grass into a tree-hole. The fact that the starling uses nesting material in the bottom of the hole, further indicates that tree-hole nesting is a relatively new phase in its nesting pattern. This is another case pointing to the Gilded Flicker and Gila Woodpecker as openers of new areas of habitation for several other species of animals, when carrying out their normal life activities, which includes saguaro tree-hole digging.

Mammals

Some members of the class Mammalia make infrequent use of saguaro tree-holes. The Big Brown Bat (Eptesicus fuscus) is found in the tree-holes during the summer in the Tucson area. These bats have been known to use large saguaro tree-holes for summer roosts (Cross and Huibregtse, 1964). I found only three bats during the summer of 1963. They were discovered on three different dates in three widely separated locations. Two of the three were found singly and on days following a night rain. The holes in which they were found had been checked both before the rain and after the observation, but in no case was further use of any of the tree-holes observed. It is possible that the bats sought refuge in the holes from the rain and were trapped there by the morning sun before they could fly back to a normal roost.

During the summer nights bats are often abundant in paloverde-saguaro communities. Leaf-nosed bats (Leptonycteris nivalis) are known to pollinate the saguaro flowers (McGregor, 1962) but none were observed in saguaro tree-holes.

All mammals are not necessarily dependent on woodpeckers for holes in saguaros. A few saguaros were observed with extensive tunnel work by packrats. And in two cases mammal nests were found in saguaro tree-holes. Exact identification is uncertain, but from the associated hair and pellets it is likely that one of the nests was that of a cactus mouse (Peromyscus eremicus) or a packrat (Neotoma albigula). It was located about eighteen feet above the ground and had no tunneling leading up to it. The other nest received extensive damage during a rain. In both cases there was no high plant under-story nearby, nor rocks by which entrance could be gained.

Invertebrates

The invertebrate fauna of the saguaro tree-hole is more abundant and varied during the summer than during winter. Insects gain entrance to the saguaro tree-hole community on the bodies of hosts as well as by their own locomotion.

Insects

The majority of invertebrates found in the tree-holes during the summer are insects. In sheer numbers, the springtail (Collembola) is best represented. These tiny insects are often found in great numbers and on one occasion when water was poured into a tree-hole, they came out actually in waves. In general they are most common in dark places among decaying organic matter and these requirements are met by many, if not most, saguaro tree-holes.

Among the insects other than the springtail, the most abundant is a member of the bedbug family. The local species (Cimidae) is closely related to the European Swallow Bug (Oeciacus vicarius). It is a nocturnal blood-feeding parasite. And in the saguaro community it is definitely associated with the owls and woodpeckers. This insect is capable of enduring sustained periods without feeding; thus many of the saguaro tree-holes even though unoccupied by birds contain small populations of bedbugs.

An occasional visitor in the tree-hole is the Desert Grasshopper (*Trimerotropis pallidipennis*). The tree-hole is undoubtedly an escape for the adult from both high air temperature and direct solar radiation. A katydid (*Microcentrum*) is a common summer resident of the understory in the paloverde-saguaro community and is infrequently found in the tree-holes.

The dipterans are represented by a species of the common mosquito (*Aedes*). These insects deposit their eggs in the holes and then die. The eggs spend most or all of the winter in this stage and when they are soaked by the summer rains the dormancy is broken. Species of this genus also mature rapidly, making the tree-hole an ideal habitat. Several nematodes were taken in the same water with the mosquito larvae. It has been shown that nematodes and nematode-like larvae of certain beetles will feed on the larvae of mosquitos (Jenkins and Carpenter, 1946).

Another dipterian found closely associated with the saguaro tree-hole was an anthomyid or root maggot (Anthomyidae). It is not the adult (which resembles a housefly) but the larval form which is found in the damaged tissue associated with new tree-hole activity.

An adult Syrphus fly (Syrphidae) was also taken in a saguaro tree-hole. While only the adult has been observed, it is quite possible that its aphid-feeding larvae could be existing on springtails.

Members of the blow fly family (Calliphoridae) were also observed in a tree-hole, associated with a dead Gilded Flicker.

The only lepidopteran was found in a larval form. This was one of the tineid moths. The larvae of this group, for the most part, are scavengers. They will feed on both feathers and dried animal matter which are found in fair abundance in the tree-holes.

Also only one hymenopteran species was found. In this case the queen of a colonial polistes wasp (Polistes flavus) started to build a nest, while alone on August 5, 1963. The nest had eight compartments by the 7th and sixteen by the 9th. This was made in a southwest facing tree-hole that was known to collect water. Soon she was joined by more and more wasps. Within a month a large nest and colony was formed. This was one of two wasp nests observed. The remains of a second colonial wasp nest was found in a different tree-hole. The wasps appeared to have guards. The guards patrolled the entrance to the hole and attacked whoever or whatever tried to disturb the colony. Under observation this appeared to be their specific duty.

The only coleopterans observed were two kinds of dermestid beetles. Both the larval and adult forms of the carrion beetle (Dermestes sp.) were found associated with decaying animal tissue in a tree-hole. A member of the genus Attagenus was found in another tree-hole associated with plant tissue. Thus the two life-forms of beetles observed, while closely related phylogenetically, they are widely separated in the ecologic niches which they occupy in saguaro tree-holes.

Arachnids

Three kinds of spiders were taken from tree-holes. None was common, as is to be expected of secondary consumers. The most common was the Giant Crab Spider (*Olios fasciculatus*). This subtropical species is well known in the southwestern United States. It both stalks its prey and spins a weak web. It is large, with females measuring up to an inch in body length.

Only one pholcid spider was detected. These spiders are very small, ca. 3 mm. in length. They construct an irregular web in dark places, and the tree-hole environment seems ideally suited.

One of the group called "wandering or jumping spiders" (Attidae) was taken from the upper part of a saguaro tree-hole. These spiders actively run about in search of prey and jump on it for capture. They make no webs except for nests in which they winter, molt or lay eggs. However, they do spin a drag line. As indicated by their name, these spiders are capable of jumping relatively great distances. Judging from habits and from infrequent occurrence, jumping spiders are more likely chance visitors than regular tree-hole inhabitants.

Another occasional occupant is the false scorpion or pseudoscorpion (Pseudoscorpionida). This relative of spiders is perfectly suited for tree-hole living. It is known to disperse by many means, even by attaching to the legs of flies (Essig, 1926). And pseudoscorpions prefer dark habitats. They spin small webs and are carnivorous, feeding on mites, psocids and minute insects in general. Springtails, which are quite numerous, constitute a major portion of the diet of the pseudoscorpion.

SUMMARY AND CONCLUSIONS

Summer temperatures inside saguaro tree-holes are markedly lower than the ambient temperatures during the critical mid-day hot period. The curves for the internal and external temperatures cross over after sunrise and sunset.

The internal tissue temperature of the saguaro is important in regulating the internal temperature of the tree-hole. As the summer progressed, the maximum internal tree-hole temperature more closely approached that of the air while this was not evident in the minimum temperature.

The humidity inside the saguaro tree-hole is higher than the ambient humidity. It rather closely parallels the outside humidity and is without as marked a time lag as observed for the internal temperatures.

Light intensity decreases with the depth of the hole. A yearly minimum intensity strikes the saguaros during the summer, associated with the maximum zenith angle of the sun. Less than one per cent of the solar radiation (visible) striking the saguaro reaches to the bottom of the tree-hole.

Many saguaro tree-holes retain water after summer rains. The period of water retention depends on the depth of the hole and its capacity to form a self-generating seal. The water is used by various desert animals, but its ecological role is not fully understood and begs further inquiry.

Birds utilize saguaros during the summer for nesting and/or roosting. There are both permanent and summer residents. The two summer residents observed were migrant Purple Martins (Progne subis) and migrant Elf Owls (Micrathene whitneyi). Both were found breeding in tree-holes during 1963. Initial tree-hole excavation is by the Gila Woodpecker (Centurus uropygialis) and the Gilded Flicker (Colaptes chrysoides), both of which are permanent residents. The Gila Woodpecker appears to be the more common of the two in the study area. Also found nesting in saguaro tree-holes are the Linnet or Housefinch (Carpodacus mexicanus), the Starling (Sturnus vulgaris) and Screech Owls (Otus asio). All are permanent residents.

Mammal occupancy of saguaro tree-holes during summer is more limited than that of birds. Mammals are both residents and visitors. The most common summer visitors are bats. The single species of bat found during the summer of observation was the Big Brown Bat (Eptesicus fuscus). The bats were found singly and on certain days which followed a previous night rain. It is concluded from observations on three such occasions that the bats were foraging at the onset of rainfall and entered the holes to escape wetting. While the Longnosed Bats (Leptonycteris nivalis) are known to pollinate the saguaro, none were observed in tree-holes. Two mammal nests were found in the bottom of tree-holes, but neither was identified with certainty. They appeared to be either packrat (Neotoma albigula) or cactus mouse (Peromyscus eremicus) nests. Observations were also made on packrat casements in saguaro trunks.

Insects were the most numerous organisms observed in the saguaro tree-holes. The summer fauna is unusually varied and shows great diversity in filling a remarkable number of niches. Springtails

(Collembola) are the most abundant. A member of the Bedbug family (Cimicidae) is the second most common insect. Katydids and grasshoppers occasionally enter saguaro tree-holes during the day to escape radiation and heated air.

Several dipterans were observed in tree-holes. Some serve as food sources. Flies are highly diversified as to niches and while all are consumers, the larvae of some may act as decomposers. The only lepidopteran was a larva of a form known to be a scavenger. Dermestid beetles were common. One group, represented by _Attagenus_, feeds on plant material and another, represented by _Dermestes_, consumes animal remains. One species of wasp (_Polistes flavus_) was found nesting.

The Arachnids are fewer in number as expected for secondary consumers. The three kinds of spiders are representative of the major spider life-forms. One species is in a web spinning family (Phlocidae), another in a hunting family (Attidae) and a third is a hunting web-spinner (_Olios fasciculatus_). A pseudoscorpion, which also feeds on springtails, gains entrance to the saguaro tree-hole on the legs of flies and other flying insects.

The contents were not examined by special methods for protozoans, the animals which may be expected to be the most abundantly present in saguaro tree-holes at certain times of the year. Nematode worms were the only non-arthropod invertebrates identified in the tree-holes during this study.

The present study has contributed approximately a dozen additional animals to the list of known occupants of saguaro tree-holes.

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Appendix A. Common and Scientific Names of Animals Observed in Saguaro Tree-Holes During Summer

Common Name	Scientific Name
BIRDS	
Purple Martin	*Progne subis*
Gilded Flicker	*Colaptes chrysoides*
Gila Woodpecker	*Centurus uropygialis*
Elf Owl	*Micrathene whitneyi*
Common Screech Owl	*Otus asio*
House Finch, Linnet	*Carpodacus mexicanus*
Starling	*Sturnus vulgaris*
MAMMALS	
Big Brown Bat	*Eptesicus fuscus*
Cactus Mouse	*Peromyscus eremicus*
Packrat	*Neotoma albigula*
ARACHNIDS	
Giant Crab Spider	*Olios fasciculatus*
Phlocid Spider	Pholcidae
Wandering or Jumping Spider	Attidae
False or pseudoscorpion	Pseudoscorpionida

Appendix A (continued)

Common Name	Scientific Name
INSECTS	
Springtail	Collembola
Desert Grasshopper	*Trimerotropis pallidipennis*
Katydid	*Microcentrum* sp.
Bedbug family	Cimicidae
European Swallow Bug	*Oeciacus vicarius*
Common Mosquito	*Aedes* sp.
Anthomyiid or Root Maggot	Anthomyidae
Syrphus Fly	Syrphidae
Blow Flies	Calliphoridae
Tineid Moths	Tineidae
Colonial or Polistes Wasp	*Polistes flavus*
Carrion Beetle	*Dermestes* sp.
Attagenus	*Attagenus* sp.
ROUNDWORMS	
Nematodes	Nemotoda