



The saguaro tree-hole microenvironment in southern Arizona, I. Winter

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THE SAGUARO TREE-HOLE MICROENVIRONMENT
IN SOUTHERN ARIZONA. I. WINTER

by

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A Thesis Submitted to the Faculty of the
DEPARTMENT OF ZOOLOGY
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
In the Graduate College
THE UNIVERSITY OF ARIZONA

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ABSTRACT

The saguaro tree-hole microhabitat in southern Arizona was studied during the winter of 1962-63. Considerable climatic modification was noted. The range of temperature within the saguaro tree-hole was found to be less than the ambient range. The cycling of the internal maxima and minima lagged behind those occurring outside by 6 to 10 hours. Because of this the internal temperature cycle was nearly opposite the ambient cycle. Relative humidity inside the hole was higher than ambient during the day and lower than ambient at night.

A winter internal examination of 51 saguaro tree-holes for large animals revealed two screech owls; of 16 holes closely inspected for insects 12 individuals were found. Rainwater drained into numerous holes, one of which retained its water for nearly two months.

The Tree-hole Microenvironment

Introduction

The internal microenvironment of the saguaro (Cereus giganteus) tree-hole habitat has been relatively little studied even though some of its inhabitants have long been known to biologists. The community succession remains surprisingly little known, particularly with regard to the invertebrates, although the initial steps of excavating and nesting by birds is commonly cited.

During January and February, 1963, the winter internal microenvironment of saguaro tree-holes was measured in some detail. It had been determined earlier (1957-1958, C. H. Lowe) that during the winter, especially in January, and during the summer, especially in June, a considerable variation exists between the ambient temperature and the internal temperature of the deep holes. It was the primary purpose of the present investigation to (1) determine the nature and extent of the diurnal and nocturnal winter variation for representative saguaro tree-holes and (2) to determine the nature and extent of the winter inhabitation.

The study has been confined to the Arizona Upland desert (Shreve, 1951) in southeastern Arizona, within a radius of 20 miles of Tucson, Pima County, Arizona. The primary study area was 1 mile east of Gates Pass in the Tucson Mountains, on the Casaday Ranch¹ at $5\frac{1}{4}$ miles

1. The home of Dr. and Mrs. L. W. Casaday, University of Arizona, College of Business and Public Administration.

west of Tucson. This site, at 2950 feet elevation, is about ten feet above the bottom of a canyon extending northward from the main Gates Pass Canyon.

Methods

Microclimatic data for the interior of saguaro tree-holes was obtained primarily from (1) installations of electrical recording thermometers, (2) electrical humidity sensors, and (3) recording maximum-minimum thermometers.

The electrical instruments were employed in two closely matched saguaro tree-holes at the major study area. One hole was exposed to the south and the other to the north. Both were in tall saguaros (27 and 30 ft.) about 12 feet apart.

The south hole faced 180° , was 25 feet from the ground and about 5 feet from the top of the plant. Its entrance was $1 \frac{3}{4}$ inches high and $2 \frac{1}{4}$ inches wide. It was about 7 inches deep and extended completely into the pith of the plant. There was a definite kink in the tree at the location of this hole (Fig. 1).

The north hole faced 340° T., was 18 feet from the ground and about 9 feet from the top of the plant. Its entrance was $1 \frac{3}{4}$ by $2 \frac{1}{4}$ inches and the hole was about 5 inches deep. This hole was also in the pith (Fig. 1). The callus lining of the south hole was 9 layers (5.1 mm.) thick near the entrance; the entrance of the north hole was 7 layers (3.8 mm.) thick.

The residents of the nearby home mentioned that during the previous season Gila woodpeckers had nested in the north-facing hole.



Fig. 1. Instrument shelter for monitored saguaro tree-holes. Arrows point to north-facing and south-facing (near kink in stem) tree-holes, at major study area in the Tucson Mountains.

During the experiments reported, Gila woodpeckers showed continued interest in both of the holes.

Sensing elements for air temperature and relative humidity were placed on the bottoms of both cavities. To keep birds from entering and damaging the probes, wire guards fashioned from clothes hangers were placed over the openings. Outside each entrance another air probe was attached one-half inch from the skin of the plant and protected from the sun by a shield. A sheltered humidity element was attached above the entrance to the north hole.

Below both of the holes (north-facing and south-facing) a thermometer was embedded with the end of the mercury bulb placed about 3 mm. under the skin of the plant.

Leads from all elements were brought to an instrument shelter located at the base of the north plant (Figs. 1 and 2). Temperature probes were plugged into a Yellow Springs multichannel telethermometer, accurate to within 1% of range ($0.5^{\circ}\text{C}.$). The telethermometer was adapted with an electric clock motor operating a stepping switch so that it could switch automatically and repeatedly through all of the sensing (air) probes within four minutes. To record temperatures over extended periods the adapted telethermometer was attached to a Yellow Springs model 80 laboratory (Rustrak) recorder. In addition, any selected probe could be read manually at any time. A special 30° resistor, plugged into one of the telethermometer channel jacks, served as a recorder reference point on the record sheets.

To maintain zero settings both the telethermometer and the recorder were kept in continuous operation. However the recorder's paper



Fig. 2. Interior of the instrument shelter (Fig. 1). Left rear, telethermometer (recorder at center; interval timer at right). Left foreground humidity instrument (junction box and meter).

drive had been rewired so that it could be controlled by an interval timer. The timer was set to allow operation, i.e., continuous recording, for 15 min. out of each hour.

The telethermometer was powered by a self-contained battery, but its automatic adaptation as well as the recorder and the humidity instrument required 115 volts. This was supplied at the nearby residence.

To summarize the field set-up, the temperature inside and outside both south and north-facing tree-holes could be read and recorded manually or all readings could be recorded automatically. The humidity sensors, one in each hole and one outside, were read from the instrument shelter and recorded manually. The thermometer in the south tissue and another in the north, were read after climbing a ladder to their locations twice each day, and once an hour during the 50-hour period noted below (Figs. 1 and 2).

To obtain checks for temperature readings and correlated humidity data, 50 continuous hours of observation were made at the location during the 16th and 17th of February, 1963 (Table 1). During this time all temperature and humidity readings were recorded manually every hour on the hour, as well as automatically (temperature).

The humidity device and sensing elements (manufactured by El Tronics, Inc. of Chicago, Ill.) were calibrated in a controlled laboratory situation.

During some periods of time, the thermister temperature recordings were found to drift up to ca. 3°C . per 12 hours. Corrections for this recorder drift and other instrument readjustments were made twice daily at the site, one in the morning at about 8:30 and again at about 4:30 p.m.

Table 1

Fifty-hour tree-hole temperature-humidity recordings for a south-facing saguaro tree-hole in the Tucson Mountains at the primary study site. Data recorded manually during mid-February, and graphed in Figs. 3 and 4.

Date & Time	Temperature (°C.)			Relative Humidity (%)	
	Ambient	Tree-hole	Tissue	Ambient	Tree-hole
1963					
2/15 12 MDT	5.1	12.8	9.5	56	47
2/16 1 a.m.	4.0	12.5	8.5	57	47
2	5.1	12.0	8.0	53	46
3	4.9	11.2	7.0	53	44
4	3.7	11.0	6.5	55	44
5	4.0	10.5	6.0	53	43
6	5.0	10.0	6.0	50	43
7	5.9	9.7	6.0	46	43
8	7.1	9.1	6.0	44	43
9	10.0	8.9	7.4	36	44
10	12.8	8.8	11.0	33	44
11	13.0	8.8	12.5	34	44
12 Noon	14.8	8.9	15.0	33	44
1 p.m.	15.2	9.0	17.0	34	44
2	15.9	9.6	17.0	33	44
3	15.9	10.4	16.2	33	44
4	14.2	11.0	16.0	33	44
5	14.0	11.6	15.2	33	44
6	12.6	11.9	14.5	33	45
7	10.8	12.2	13.0	32	46
8	8.9	12.3	11.1	40	46

Table 1 (continued)

Date & Time	Temperature (°C.)			Relative Humidity (%)	
	Ambient	Tree-hole	Tissue	Ambient	Tree-hole
9	8.1	12.3	10.9	42	46
10	7.1	12.4	9.9	49	47
11	6.3	12.2	9.0	52	48
12 MDT	5.6	12.0	8.0	54	47
2/17 1 a.m.	6.1	11.7	7.5	56	48
2	8.0	11.1	7.5	44	47
3	9.8	11.0	7.5	37	46
4	8.9	10.7	8.0	37	45
5	8.6	10.2	8.1	36	44
6	8.9	10.0	8.0	36	44
7	10.0	9.9	8.2	35	44
8	10.3	9.8	8.8	34	44
9	11.6	9.6	10.0	34	44
10	12.6	9.5	12.5	32	44
11	14.9	9.5	14.3	33	45
12 Noon	15.6	9.5	15.5	33	45
1 p.m.	20.9	10.1	20.6	34	45
2	18.6	11.1	23.3	32	44
3	17.2	11.8	24.0	34	44
4	19.7	12.6	23.7	32	45
5	18.1	13.0	24.4	33	45
6	14.0	13.5	21.8	34	46
7	13.4	13.8	19.4	32	47
8	11.4	14.2	16.0	32	50
9	11.8	14.3	15.2	34	51
10	10.8	14.3	14.0	34	51
11	9.3	14.4	12.8	31	50
12 MDT	7.8	14.1	11.8	41	49
2/18 1 a.m.	7.9	13.9	10.8	44	47

Temperature and Humidity

All data for temperature and relative humidity reveal that conditions within saguaro tree-holes are much less variable over the 24-hour period, and less extreme, than those occurring externally. Both the extent of the microclimatic modification and the greatness of the time lag between internal and external extremes are especially marked.

Data for a south-facing hole, obtained in mid-February during two partly cloudy days (the first more than the second) is graphed in Fig. 3. For Fig. 3, the line representing external air temperature moves to daily highs and lows with marked secondary variations while tree-hole air temperatures maintain a relatively steady pattern. The humidity is also relatively stable in the hole (Fig. 4).

The temperature of the saguaro tissue, taken just under the skin of the plant, rises during the day to a level higher than the ambient air temperature. The ambient air temperature drops quickly at sundown. However, because of the great quantity of water in the tissue (ca. 90% water, McDougal, 1926), heat from the tissue is lost very slowly. Loss of tissue heat continues to warm the air within the tree-hole until a maximum is reached. This tree-hole maximum occurs several (8-10) hours after the ambient air temperature peak (between 9:00 and 12:00 p.m. in February). After the tissue temperature drops below the tree-hole air temperature, the latter begins to cool.

In the present study the very deep tissue temperatures were not recorded. Therefore, the tissue temperature (for near skin surface) graphed in Fig. 3 more closely follows the ambient temperature curve and

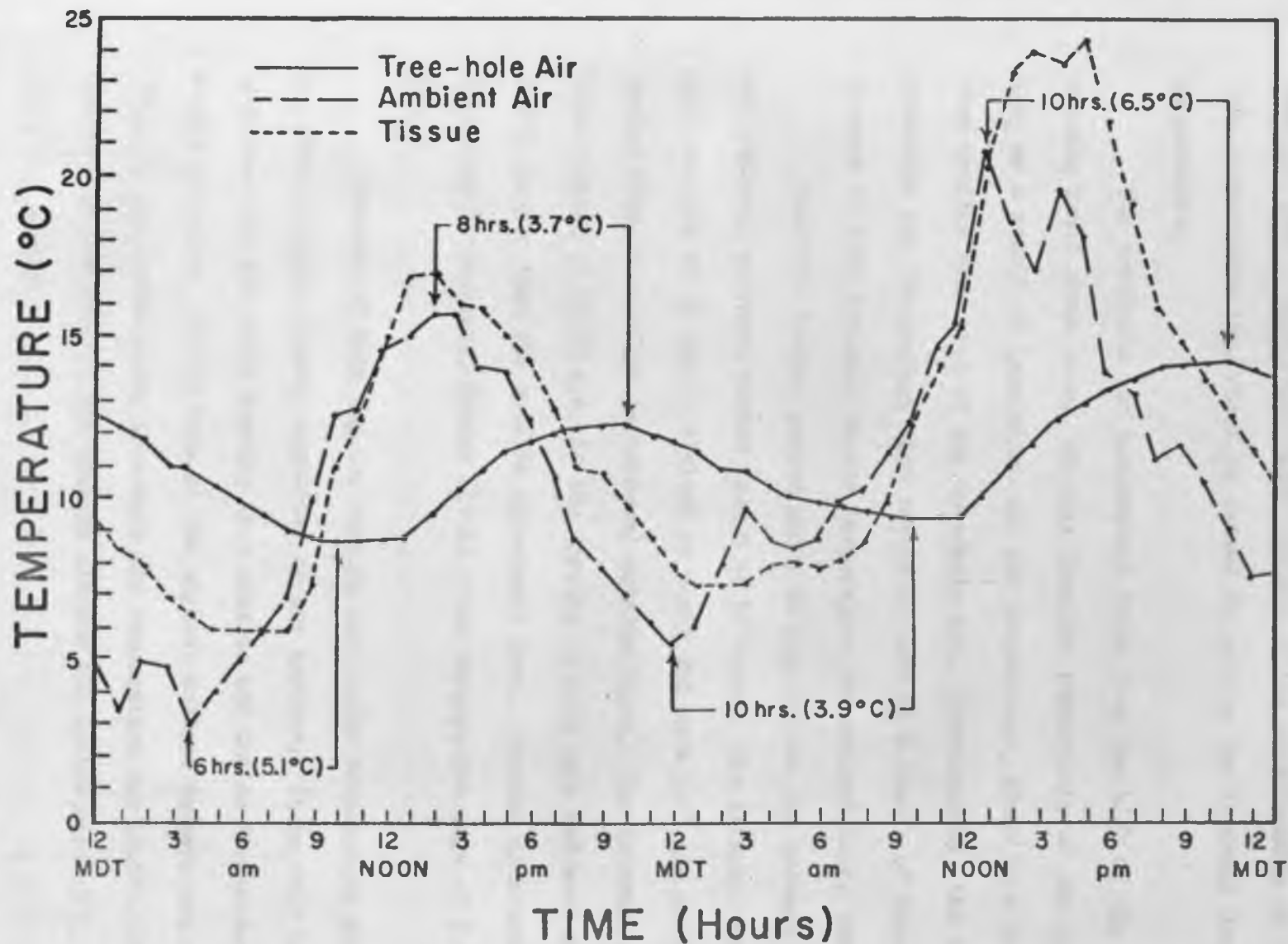


Fig. 3. Saguaro tree-hole air temperature, ambient temperature, and tissue temperature during a 50-hour period in mid-February. The time lag and the difference in temperature between maximum or minimum ambient and the tree-hole temperatures is shown for a south-facing hole. Data in Table 1.

does not give a completely clear picture of the relationship of the tree-hole temperature lag, which is caused in part by the internal deep tissue temperature.

The tree-hole air temperature drops from the high of the previous evening until about noon. At this time the temperature of the tissue has, as a result of insolation and air temperature, risen to a temperature greater than that of the tree-hole air. Consequently, the internal tree-hole air temperature then begins to warm as a result of these increases in both internal tissue temperature and ambient (air) temperature.

Over the 50-hour period shown in Fig. 3, the lag between external and internal extremes varied from 6 to 10 hours. The internal maxima were reached at 10 and 11 o'clock at night and were 3.7° and 6.5°C . cooler than the earlier (afternoon) outside highs. The internal minima were reached at 10:00 a.m. in the morning on both days and were 5.1° and 3.9°C . warmer than the outside (pre-dawn) lows. Working with tree-hole dens used by raccoons, Stains (1961) found temperature lags of 2 to 5 hours.

Because of this lag the outside and inside temperature patterns are complimentary (nearly opposite) to one another. It is only in the early morning and early evening that outside and inside temperatures nearly coincide. At the time of the highest ambient temperature recorded (Fig. 3) the south-facing tree-hole air temperature was 10.8°C . (19.4°F .) cooler. At the time of the outside minimum the inside was 7.3°C . (13.1°F .) warmer.

Park (1954) examined the microclimate of a tree-hole in a black cherry tree in Indiana, and found that at an ambient high of 82°F .

(27.8°C.) the tree-hole air temperature was 6°F. (3.7°C.) cooler.

Hensley (1954) observed in Organ Pipe Cactus National Monument, Arizona, during February through August that the covered nests of the cactus wren and verdin were slightly lower in temperature compared to the open nests of different species; Anderson (1963) observed in Tucson during June and July that the temperature within covered cactus wren nests was equal to ambient (details were lacking).

During the same 50-hour period of monitoring noted above, the outside relative humidity followed the typical pattern of daytime lows and nighttime highs (Table 1, Fig. 4). Inside the hole the relative humidity was more constant. It was above the outside humidity by day, rising slightly at night, but remaining lower than the outside throughout the night. At the height of a winter rainstorm during January 11, the relative humidity was ca. 95% outside and ca. 65% inside.

To insure a record of thermal relationships for the coldest day of the winter, the automatic recorder was kept in operation during January. Ten days of maximum-minimum temperature from this continuous record, this period includes January 13, the year's coldest day, are shown in different relationships in Figs. 5-8 and are summarized in Table 2; raw data is presented in Table 3.

There are significant differences between north and south facing holes. Both the outside and the inside temperature extremes were higher (warmer) for the south-facing hole. The abnormal relationship between outside and inside maximums on January 19 was caused by an unusual drop in the air temperature throughout the day, without a normal afternoon

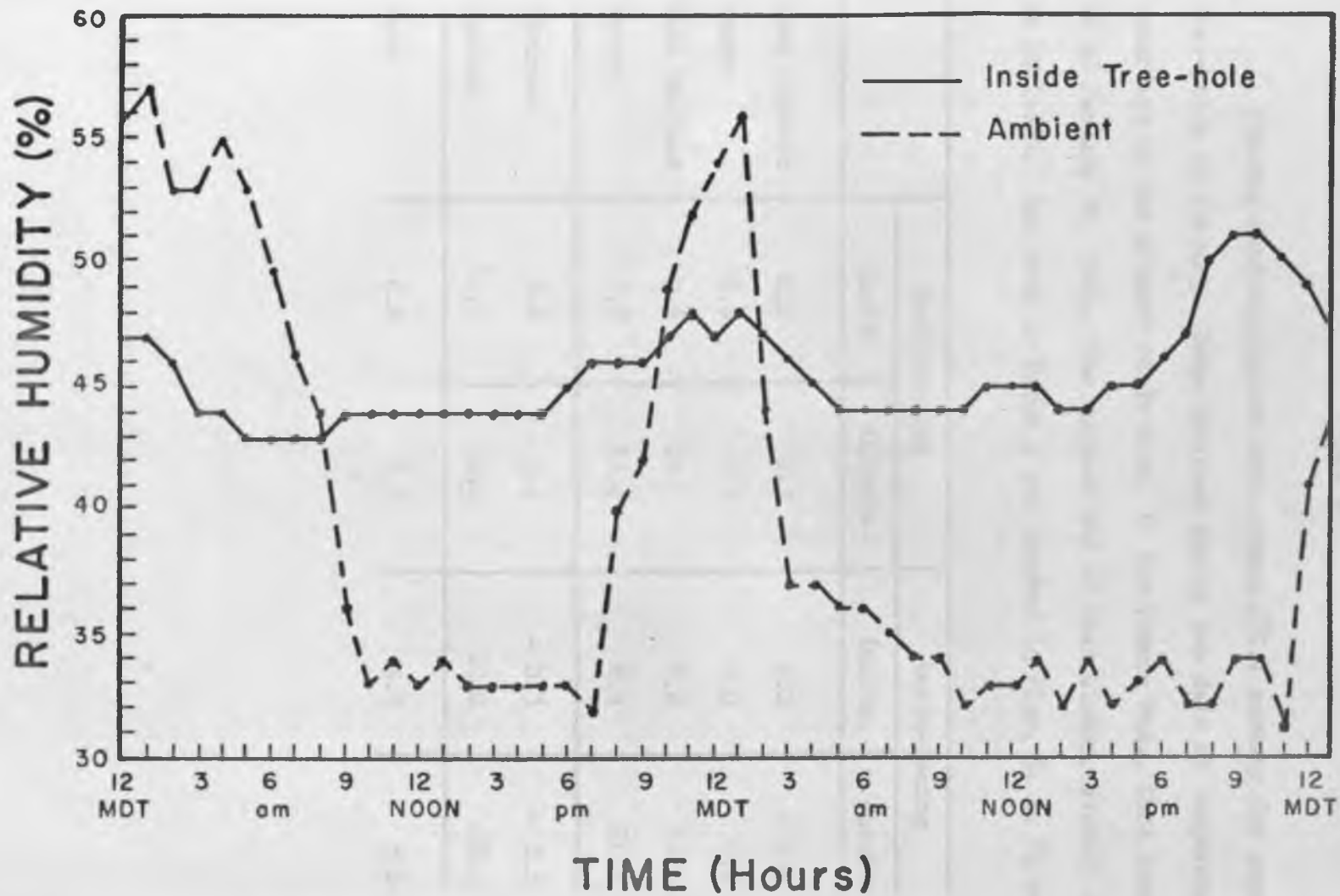


Fig. 4. Relative humidity inside and outside a south-facing saguaro tree-hole during a 50-hour period in mid-February. Data in Table 1.

Table 2

Ten-day maximum-minimum temperature ($^{\circ}\text{C.}$) summary for saguaro tree-holes in January. Data obtained during ten days of temperature recording at the primary study site, in the Tucson Mts., from January 12 to January 21, 1963. The coldest day of that winter, January 13, is included. Raw data in Table 3 and graphed in Figs. 5, 6, 7, and 8.

	South-facing		North-facing	
	Inside	Outside	Inside	Outside
Mean Minimum	4.0	0.3	3.0	- 0.4
Range	6.8	7.7	7.0	7.0
Mean Maximum	9.6	15.1	8.8	12.1
Range	8.2	15.4	8.8	16.4
Minimum	0.6	- 4.4	- 0.3	- 3.5
Maximum	12.5	24.2	12.0	21.3
Mean	6.8	7.7	5.9	5.4

Table 3

Raw data for temperature ($^{\circ}\text{C}.$) summary given in Table 2.

Graphed in Figs. 5, 6, 7, and 8.

Date	Maximum				Minimum			
Jan.	South		North		South		North	
1963	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
12	7.8	10.0	6.8	7.6	5.3	-1.6	3.0	-1.6
13	4.3	8.8	3.4	4.9	0.6	-4.4	-0.3	-3.5
14	6.7	11.7	5.6	9.6	1.5	-4.0	-0.1	-4.1
15	10.1	18.0	8.8	13.4	2.0	-0.9	1.2	-1.7
16	12.0	21.2	11.0	16.1	5.1	3.3	4.2	1.8
17	12.5	20.1	12.0	15.6	6.5	1.9	5.0	1.7
18	12.2	15.8	11.7	15.7	6.8	2.3	6.3	1.7
19	11.3	9.4	11.3	9.0	7.4	0.6	6.7	0.7
20	7.0	12.0	7.2	7.8	1.5	-2.2	0.8	-1.7
21	12.4	24.2	10.2	21.3	3.6	3.3	3.2	2.9

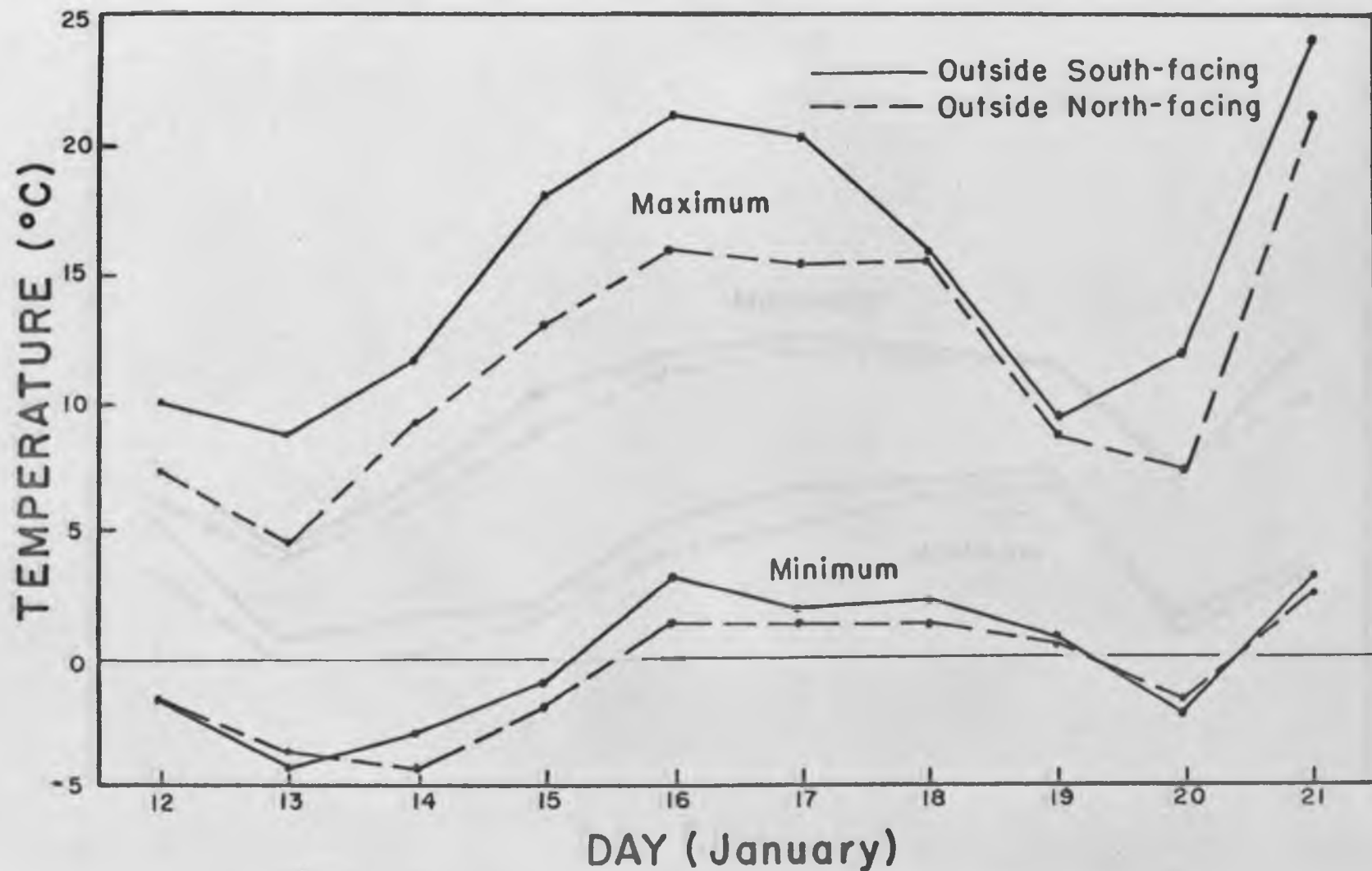


Fig. 5. Daily maximum and minimum temperatures outside a south-facing and a north-facing saguaro tree-hole between the 12th and the 21st of January, 1963. Data in Table 3.

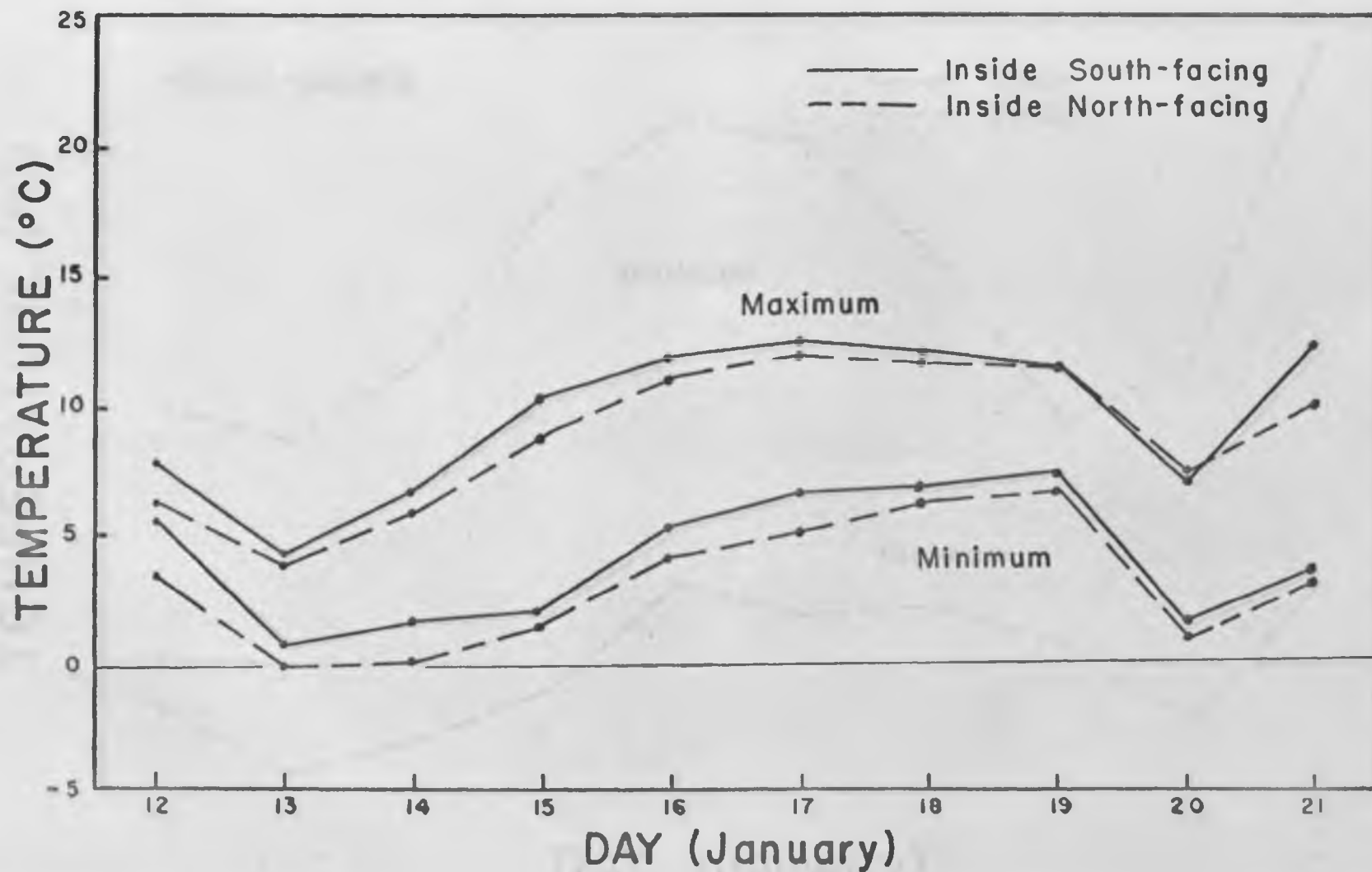


Fig. 6. Daily maximum and minimum temperatures inside a south-facing and a north-facing saguaro tree-hole between the 12th and the 21st of January, 1963. Data in Table 3.

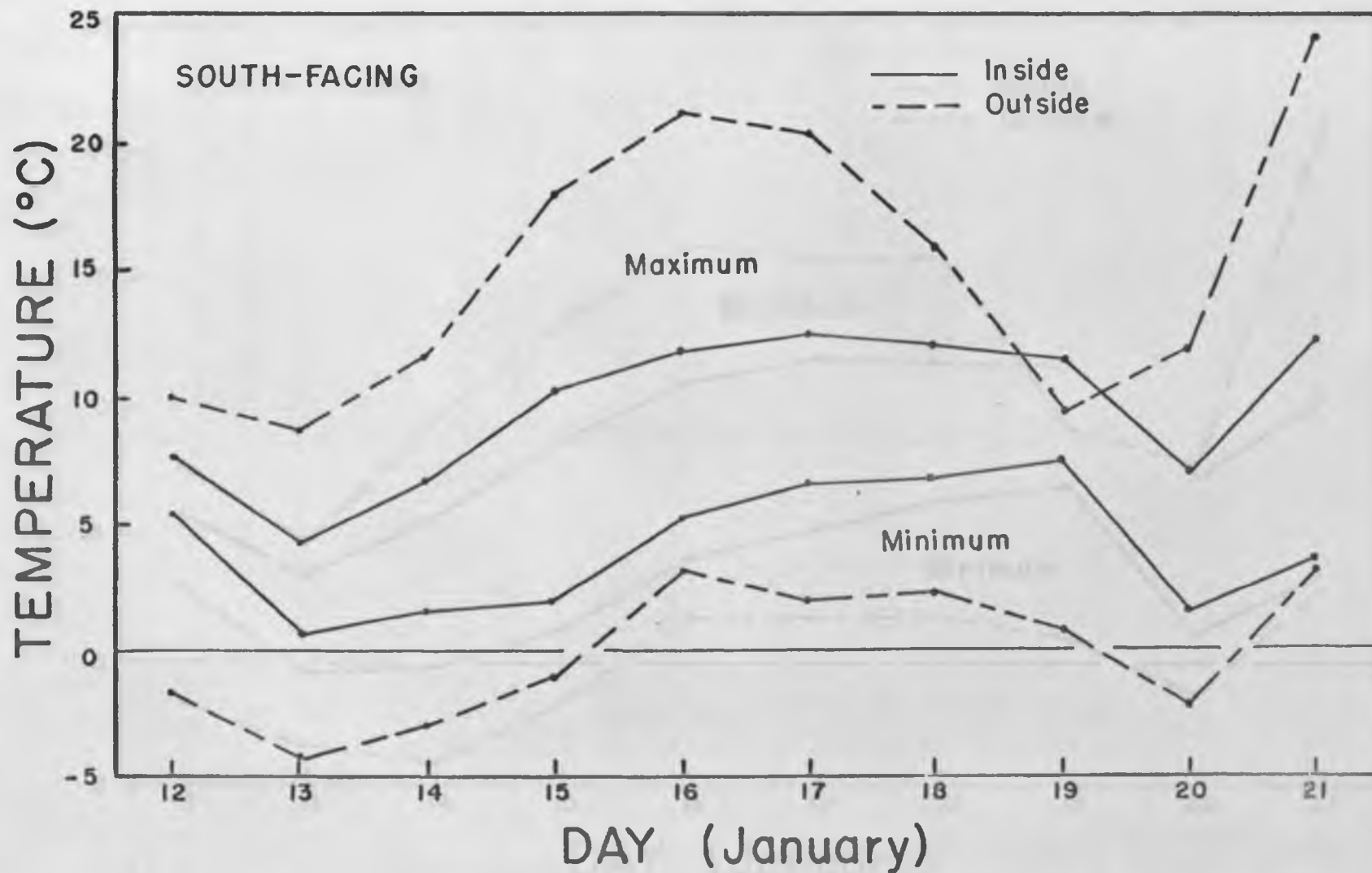


Fig. 7. Daily maximum and minimum temperatures inside and outside a south-facing saguaro tree-hole between the 12th and the 21st of January, 1963. Data in Table 3.

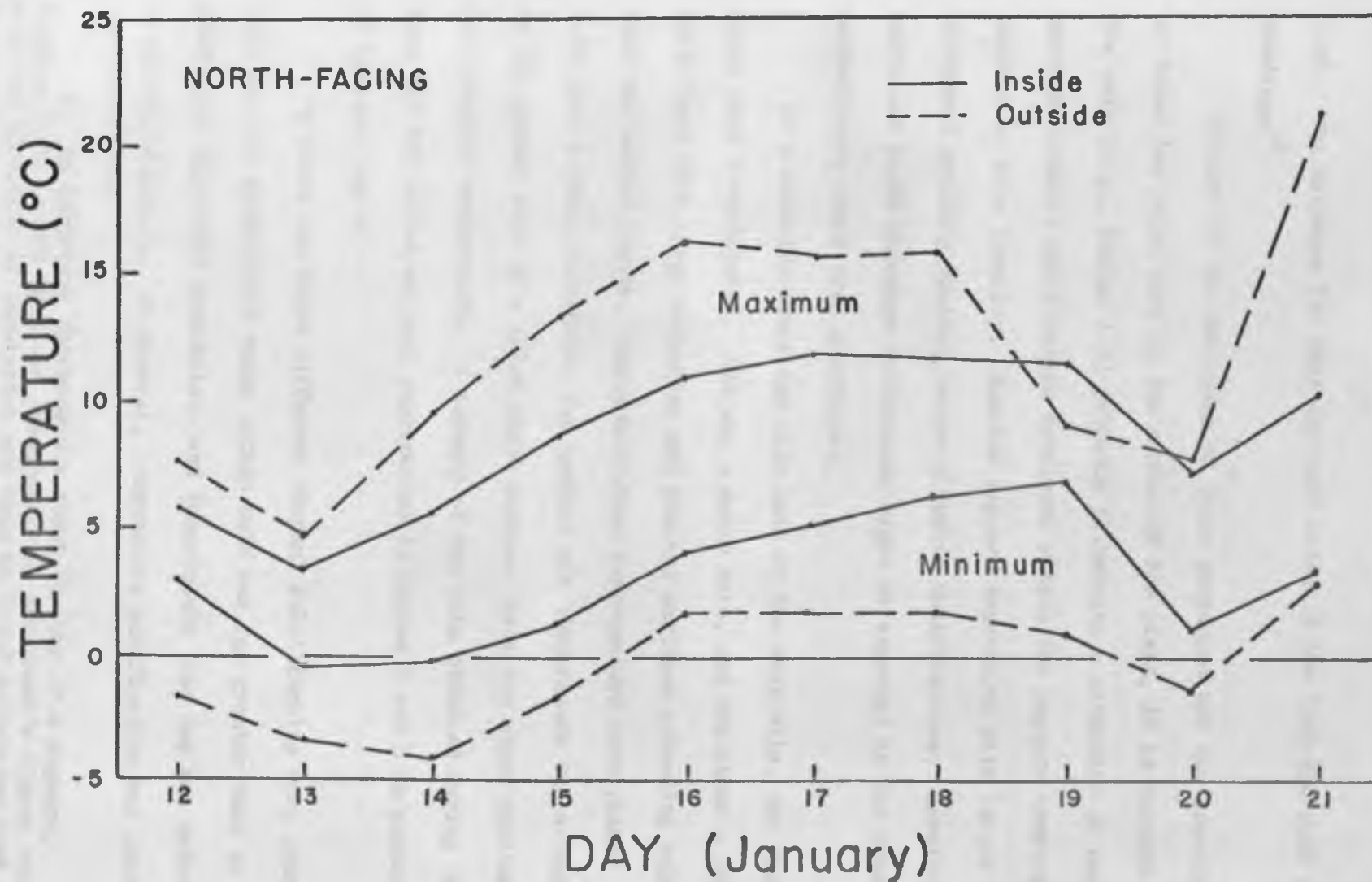


Fig. 8. Daily maximum and minimum temperatures inside and outside a north-facing saguaro tree-hole between the 12th and the 21st of January, 1963. Data in Table 1.

high. The maximums for that day were actually the 1:00 and 2:00 a.m. readings.²

Because of the smallness of their entrances and the location of these two holes deep in the center of the plant, it is thought that the data (e.g., Tables 1-3) probably illustrate a situation of near maximum climatic modification developed within the saguaro tree-hole habitat at this locality. Shallow saguaro tree-holes with larger entrances probably realize lesser climatic modifications. Greater north and south exposure differences might be expected in the tree-hole microclimate under such conditions.

At a location about one mile east of the main site, two such holes were investigated. One was a south hole, and the other a north hole, both with large entrances and shallow cavities extending only into the cortex tissue. Maximum-minimum thermometers were placed in both, and another instrument for ambient air temperature was attached on the shaded side of a third plant between these two stems monitored for internal temperature. A summary of the data obtained during the same ten day period as that represented in Tables 2 and 3 is presented in Tables 4 and 5.

In these two holes different thermal relationships were found. This is, the temperature range within both was far greater than in the previously discussed tree-holes, and temperature time lag was undoubtedly of shorter duration. In general, temperature modification was less

2. By inserting thermometers about the top of a saguaro, Johnson (1924) noted that the temperature of the plant's tissue varied with the direction of insolation and this he found correlated with the developmental sequence of the flowers.

Table 4

Ten-day maximum-minimum temperature ($^{\circ}\text{C}.$) summary from dissimilar saguaro tree-holes in January. Data obtained during ten days, January 12 to January 21, 1963, from maximum-minimum thermometers which were kept within dissimilar saguaro tree-holes in plants in the Tucson Mts. about one mile east of the primary study area. The coldest day of that winter, January 13, is included. Raw data in Table 5.

	Inside		Outside
	S.-facing	N.-facing	
Mean Minimum	2.3	2.9	-0.6
Range	9.4	8.9	12.3
Mean Maximum	17.6	9.9	16.8
Range	11.1	10.5	12.8
Minimum	-1.1	-1.1	-5.6
Maximum	22.8	17.2	22.2
Mean	10.1	6.4	8.7

Table 5

Raw data for temperature ($^{\circ}\text{C}.$) summary given in Table 4.

Jan. 1963	Maximum			Minimum		
	North	South	Outside	North	South	Outside
12	11.1	13.3	13.9	5.0	4.4	1.7
13	6.7	11.7	9.4	-1.1	-1.1	-5.6
14	8.9	14.4	12.8	0.6	-0.6	-3.9
15	6.7	18.3	17.2	0.6	0.0	-2.2
16	8.9	20.0	18.3	3.3	2.8	0.0
17	10.6	20.6	18.9	4.4	3.9	1.1
18	10.6	19.4	20.0	5.6	3.9	1.7
19	17.2	22.8	22.2	7.8	8.3	6.7
20	8.9	15.0	13.9	0.0	-0.6	-4.4
21	9.4	20.6	21.1	2.8	1.7	-0.6

extensive. Because of direct and rapid insolation, maximum temperatures within the south hole were much higher than in the north, and often exceeded ambient readings. The south-facing hole, less deep and with a larger entrance, had a slightly lower mean minimum temperature.

Water

Eight of the 51 tree-holes examined were found to have collected some quantity of rainwater. The percentage (16%) might have been larger if all holes had been examined immediately after rains.

The efficiency of saguaro tree-hole water capture depends on (1) entrance configuration (entrance width, protruding lower lip, indented upper lip) enabling water to drip into the hole; (2) vertical position, holes occurring lower on the stem have larger collection surfaces above the entrance; and (3) entrance exposure, i.e., exposure to the prevailing direction of rainfall (Fig. 9).

The quantity of water captured can be considerable. During a 0.81 inch rainfall (Tucson Airport) on February 10 and 11, one saguaro tree-hole in the study area collected over 7 inches of water. During a 0.25 inch rainfall on March 17th, this same hole collected $3\frac{1}{4}$ inches. Water retention depends upon the size of the entrance, the depth of the cavity, the condition of the tree-hole callus (see below), the time of the year, and the general weather.

The inner layers of the callus of those holes which collect water usually soften and disintegrate; some of the plates of callus float and possibly provide a shield against evaporation. Although many of the holes which collect water retain it for only a few days, others



Fig. 9. A saguaro tree-hole showing entrance configuration with protruding lower lip suitable for the capture of rainwater draining from above.

retain it for several weeks or longer. The above-mentioned cavity retained the February water collection for 29 days and the March collection for 9 days. Comparison with other tree-holes reveals that this hole does not offer a maximum situation for either rain capture or retention.

Somewhere in the Arizona Upland desert there are perhaps cavities which maintain water even through the hot, dry months of April, May, and June. The climatic record for Tucson (Airport) shows an average precipitation of 0.28 inches for each of these months of the fore-summer drought (April-June). Should there be an average rainfall or better, there is the possibility of an occasional hole retaining water over this period. About every five years little or no rain falls during this period (U. S. Weather Bureau annual summary with comparative data, Tucson, Arizona) and the chances of a hole retaining water are accordingly reduced.

The importance of these storages with regard to the saguaro mosquito (possibly a new, undescribed species) is obvious. They are also without doubt an important source of drinking water for birds, and possibly for bats and insects. On January 15, 1963 at 3:45 p.m., a gilded flicker was observed drinking from a saguaro tree-hole at the study area. Several days later, in the evening, a house finch was noted drinking from a different hole.

Animal Species

In addition to living animals, all of the 51 sahuaro tree-holes inspected during the winter contained only small amounts of refuse.

One of the principal reasons for this is that the majority of the tree-hole inhabiting birds, woodpeckers and owls, do not bring in twigs and grass for nest building, but simply lay their eggs on the few remains at the bottom of the chamber. On March 1, 1963 extreme care was exercised in sampling the contents of 15 holes. The largest samples from these holes were about 50 ml. in volume and were comprised mostly of assorted insect fragments from decomposed bird droppings, bits of the woody cavity lining, and occasionally, a few hard seeds. Four samples contained small bones and mammal hair. These four were from holes over 9 inches in depth and had evidently been used by owls or other birds of prey.

Birds

Saguaro tree-holes in southern Arizona are used as nesting sites not only for the two species which excavate them, the Gila woodpecker and gilded flicker, but by other species as well.

Bent (1939) infers that in the breeding season (this appears to be April, May, and June) desirable saguaro tree-holes may be at a premium. It was proposed by von Haartman (1957) that hole nesting birds are more successful than non-hole nesting birds of the same species and that, therefore, there is an evolutionary trend toward hole-nesting. Willard (1912) found the elf owl, screech owl and ash throated flycatcher nesting in saguaro tree-holes. He also found the nest of a cactus wren in a large open cavity. Gilman (1915) adds to the list the pigmy owl, Arizona crested flycatcher and sparrow hawk, and states (p. 163) that "Once a Bendire Thrasher made her nest in one with a crack in one side

that let in light enough for her. In a partly excavated hole I found the nest of a Western Kingbird, and in another the nest of a House Finch." Gilman (1915) further states that he once saw a tree-hole occupied by a Lucy warbler. Bent (1939) includes the purple martin, and Howes (1954) lists the blue-bird and describes the nesting of a pair of English sparrows in a saguaro tree-hole. Dr. J. T. Marshall (pers. comm.), University of Arizona, found starlings (Sturnus vulgaris) moving into saguaro tree-holes, and Mr. Dwight Warren, Chief Naturalist, Saguaro National Monument, was told of a lark bunting (Calamospiza melanocorys) possibly using a cavity.

Most of the birds listed above are not winter residents. Only the two woodpeckers, screech owl, cactus wren, sparrow hawk, English sparrow and starling are winter residents, and of these only the woodpeckers and screech owl commonly inhabit saguaro tree-holes.

Of these three, only the screech owl is known for certain to roost in holes throughout the year. While examining holes during this investigation in December, two screech owls were found, each in a separate hole. Both were discovered during the daytime, quietly sitting on the bottom of their chamber and when disturbed they snapped their beaks but they were quiet when drawn into the sunlight. In their holes there were only a couple of pellets and the insect, bone, and hair remains common to other holes. One of the screech owls was brought to the University of Arizona for inspection and banding (U.S.F.W.S. No. 505-26357). This bird was kept overnight and returned to its hole in the morning. Both cavities were revisited during the following month but neither was found occupied.

During January and February, while the two tree-holes at the Casaday's Ranch were instrumentated and barred with wire guards, Gila woodpeckers were noted to be continually curious. The original small guards were removed, apparently by Gilas, the temperature elements thrown from the holes and the insolation of the wire leads pecked.

Immediately after the instruments were finally removed in late February, the north-facing hole was found to have been deepened from 5 inches to 9 inches. Late in the day on April 26 an elf owl was discovered in the cavity. After being disturbed it flew from the hole and was not present the following day.

No investigations after dark were made here until 8 p.m., May 7, when a male Gila woodpecker was found sitting in this same hole; one was again found on May 11. The possibility exists that these birds roost in saguaro tree-holes during winter as well as summer. This may have been territorial behavior, *i.e.*, guarding of the nest cavity for the immediate future use by a pair, for on May 17 (six days later) four eggs were found in this hole. The hole was again barred with instruments on May 24 at the initiation of the summer microclimate study.³

Mammals

It has recently been reported by Niering, Whittaker, and Lowe (1963) that wood rats (Neotoma albigula) have eaten circular staircases through the cortex tissue of saguaros, and Howes (1954) also mentions

3. An investigation of summer aspects of the saguaro tree-hole microclimate is currently under study by Mr. Oscar Soule of the Department of Zoology.

rats and mice as tree-hole inhabitants. No rodents, their nests, or pathways were found in saguaros during this study. Hair taken from several saguaro tree-holes was examined microscopically and found not to be from wood rats and no identifiable rodent feces were found.

There is a specimen of the big brown bat (Eptesicus fuscus) deposited in the mammal collection of the University of Arizona (Department of Zoology), collected by Stephen P. Cross on August 7, 1962. The label by Cross reads, "taken by a hand net as it flew from a hole in a saguaro." The configuration of the usual saguaro tree-hole does not preclude it from use by bats, either for temporary night roosts or for day roosts for some species. Although this winter study revealed no bats, the matter merits investigation.

Reptiles

As might be expected in the winter, no lizards nor snakes were found in saguaro tree-holes. Gilman (1915) mentions that "A big 'rough neck' scaly lizard frequents the holes when they are not too high in the cactus. . ."⁴ Both Brandt (1951) and Howes (1954) state that lizards and snakes are found in the holes but, unfortunately, gives no further comment. Bent (1939, p. 301) tells about finding a large gopher snake (Pituophis) coiled inside of a saguaro tree-hole occupied by gilded flickers. The snake "had killed and half swallowed, head first, one of the large young."

4. Undoubtedly Sceloporus magister, the desert spiny lizard or Sceloporus clarki, Clark's spiny lizard.

Among other snakes in paloverde-saguaro communities, three in particular would be nominated as species possibly frequenting tree-holes. Two are the able climbers and occasional bird-feeders Masticophis piceus (red or western black racer) and M. bilineatus (Sonoran racer). However, neither species has yet been found in saguaro tree-holes, although the red racer has been observed climbing limbs of saguaros surrounded by paloverde nurse plants. The common western king snake (Lampropeltis getulus), has been observed in paloverde, ironwood, and mesquite trees eating birds and bird eggs, and has been observed partly inside a saguaro tree-hole presumably examining it for something to eat (C. H. Lowe, pers. comm.).

In both Sonora and Baja California, Mexico the large spiny-tailed iguana (Ctenosaura hemilopha) inhabits tree-holes in the cardon (Cereus pringeli), a closely related and even larger columnar species than the saguaro (C. H. Lowe, pers. comm.).

Insects

A total of ten live insects were found in samples from 15 tree-holes. Seven were ticks (order, Acarina) and were identified (by Glen M. Kohls, Public Health Service Institute, Hamilton, Montana) as Argas brevipes (nymphs). Hubbard (1899) also found ticks of apparently the same species in saguaro tree-holes near Tucson. According to Kohls, Hoogstrad, and Clifford (1961) adults and nymphs of this tick have only been found in tree-holes of the saguaro and cirio (Idria columnaris). Hosts of the larvae are mainly woodpeckers and owls of this tree-hole complex.

Of the remaining insects two were immature Lygaeidae (Hemiptera) and one was a parasitized pupa of a Lepidopteran.

After discovering that saguaro tree-holes collect rainwater, a 0.2 quart (0.2 liter) sample, about half of that present, was removed from a cavity on March 1; the last rain had occurred on February 10th and 11th. It was amber in color, had the odor of saguaro tissue, and contained two mosquito (Diptera) larvae. One was preserved immediately; the other was kept for 19 days when it became adult. Both were examined and found to belong to a group of southwestern tree-hole mosquitos but did not match any described species. Apparently this is a new species.⁵

The saguaro tree-hole is a previously over-looked breeding place for mosquitos in the Arizona Upland desert, and appears to harbor a distinctive saguaro tree-hole species in the tree-hole evolutionary group.

It was proposed by Hubbard (1899) that insects and disease gain access to healthy saguaro tissue through tree-holes, especially those in which water collects. No examples of such invasions were found during the present study. Santana (1961) investigated the immature Diptera associated with the "rot pockets" of saguaros infected with bacterial necrosis. Although no detailed study has been made of the invertebrates of saguaro tree-holes, Park (1950, 1954) emphasized the invertebrate fauna of tree-holes in the deciduous forest of the eastern United States.

5. The mosquito material, and the general problem, is currently under investigation by Mr. Anthony Ross of the Department of Zoology.

Summary and Conclusions

The tree-hole habitat (microenvironment) in the saguaro giant cactus (Cereus giganteus) was investigated in southern Arizona during the winter of 1962-63.

Simultaneous recordings of temperature and humidity both inside and outside tree-holes during January and February revealed the internal tree-hole microclimate to be markedly less variable and less extreme.

Temperature minima and maxima within the tree-hole lags behind the corresponding external values by 6-10 hours. The measured external extremes exceed those within the hole by ca. 3.5-6.5°C. (6.3-11.7°F.). Directional exposure and cavity configuration significantly affect the temperature and microclimate of the tree-hole. In all cases examined, southern exposure provided warmer thermal levels within the saguaro tree-hole.

Humidity within the tree-hole was higher during the winter day, and rose slightly at night but was less than the external night humidity. During and immediately after winter rains, the internal tree-hole humidity also rises, but remains lower than that outside.

During January and February, saguaro tree-holes contain primarily small amounts of insect and bone debris left from the activities of birds.

Of 51 holes examined only two contained screech owls. In 16 tree-holes examined closely for live insects, 12 individuals representing 4 orders (Acarina, Hemiptera, Lepidoptera, and Diptera) were found. One of the insects found is apparently a new species of tree-hole mosquito.

Water from winter rains collected in 16% of the tree-holes studied. During a 0.81 inch winter rainfall, one hole collected over seven inches of water, and retained this water for approximately a month (29 days). The storage of rainwater in saguaro tree-holes provides a drinking supply for birds and other animals, and a breeding site for mosquitos.

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