OBSERVATIONS ON MICROCLIMATE IN HABITATS OF SOME DESERT VIPERS IN THE NEGEV, ARA VA AND DEAD SEA REGION

Michael R Warburg

OBSERVATIONS ON MICROCLIMATE IN HABITATS OF SOME DESERT VIPERS IN THE NEGEV, ARAVA AND DEAD SEA REGION

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INTRODUCTION

The following is an attempt to describe the microclimate in the habitats of some desert vipers, as indicated by temperature and humidity measurements taken in midsummer.

The most important factor for life in desert is undoubtedly water, next to it and in connection with it, is the temperature. As has been shown in the study by SCHMIDT-NIELSEN and SCHMIDT-NIELSEN (1950), the higher humidity prevailing in the burrow is significant for the water balance of the kangaroo-rat. It enables the animal to conserve water, so does also the lower temperature inside the den. These two factors, temperature and relative humidity, were studied in typical habitats.

Previous climatological studies in the Negev Desert are described in ASHBEL (1951), Israel Meteorological Service (1952, 1958), KATSNELSON (1959) and MANÈ (1958). All those are concerned with general data for the Negev. So far, there have been no microclimatic data for this area.

The subject of microclimatology in arid regions is discussed and reviewed by THORNTHWAITE (1956), GEIGER (1957), WELLINGTON (1957), MESSENGER (1959), and CLOUDSLEY-THOMPSON (1962). Specific

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studies on the microclimatic conditions in habitats of certain groups are also known. Thus in connection with insectan ecology these studies have been reviewed by UVAROV (1931, 1957), PRADHAN (1957) and BODENHEIMER (1958). Microclimatic studies in habitats of desert isopods are by EDNEY (1958), CLOUDSLEY-THOMPSON (1956) and WARBURG (1965*a*). Microclimates in reptilian habitats have been studied by SERGEYEV (1939), ANDREYEV (1948,, NORRIS (1953), FITCH (1956), CURRY-LINDAHL (1956), SAINT-GIRONS & SAINT-GIRONS (1956), and WARBURG (1965*b*, *c*). In rodent habitats, microclimates were observed by VORHIES (1945), SCHMIDT-NIELSEN and SCHMIDT-NIELSEN (1950), and PETTER (1953).

The following account is a description of some thermohygrograms derived from measurements that were taken in the microhabitats of the desert vipers *Aspis vipera* (L.), *Aspis cerastes* (L.), and *Echis colorata* Günther, at four stations in the arid region, and two stations in the coastal plains of Israel.

MATERIALS AND METHODS

The following instruments were used in this study : 1) A Tele-Thermometer manufactured by Yellow Springs Instruments Co., the range of which was 0-50 °C, the readability 0.2 °C and the accuracy ± 0.5 °C. 2) Thermistors of the 'bead' type (air temperature), or 'banjo' type (ground temperatures). 3) For when the temperature exceeded 50 °C (on ground in sun), a glass thermometer of 0.1 °C readability. All temperature measurements in the sun were made with shielded elements. 4) For humidity measurements, an electrical hygrometer was used together with Lithium Chloride elements manufactured by El Tronics Inc. This hygrometer (see Warburg, 1965*a*), had an accuracy of ± 2 % and a readability of 1 % R.H. 5) The humidity of the air was also measured using a sling psychrometer with a readability of 0.1 °F.

The data are presented as thermohygrograms in which each point represents the temperature and humidity at the hour of measurement. The measurements on each occasion were taken at two hours intervals during the day, and once or twice at night, for a period between 24-48 hours.

RESULTS AND ANALYSIS

Measurements were taken at four stations in the desert and two stations in the mediterranean region in the coastal plains. For the description of sites at each station where temperature and humidity were measured, see the legend of each figure.

Station 1. Revivim

This station was located in a large area of shifting sand dunes which is an extension of the coastal sand dunes into the north-western Negev. The area is located in the Sahara-Sind region. Precipitation is irregular and around 100 mm rain annually. The driest and hottest months of the year are from June until August. The site of the station was 4 km northwest of the settlement at a place where several bushes of *Artemisia monosperma* and *Roetama roetama* were growing. In a nearby sand wall several holes of insects, reptiles and rodents could be seen. Such a locality of shifting sand dunes is a typical habitat of *Aspis vipera.* Other reptiles found in that area are listed in the appendix.

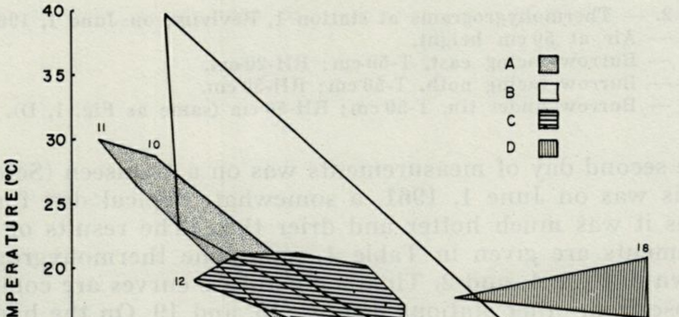

Fig. 1. — Thermohygrograms at station 1, Revivim, on March 18/19, 1961.
A — Air at 50 cm height.
B — Ground, on surface of sand.
C — Burrow facing north, T-40 cm; RH-40 cm.
D — Burrow under tin, T-50 cm; RH-50 cm.

The first day of measurements was on March 18/19, 1961. This was after a few rainy days, but the surface of the sand was already dry. The hole ('C' in Fig. 1), was occupied by *Acanthodactylus scutellatus,* whereas at site ('D' in Fig. 1), one *Chalcides sepsoides* was found. The two remaining holes (Fig. 16, '4', and Fig. 2, '2') were occupied by *Gerbillus* sp. The sun reached the place at 0530 and sunset was at 1600. During the whole day carnivorous ants (*Cataglyphis* sp.), and tenebrionid beetles (such as *Pimelia* sp.) could be seen active on ground.

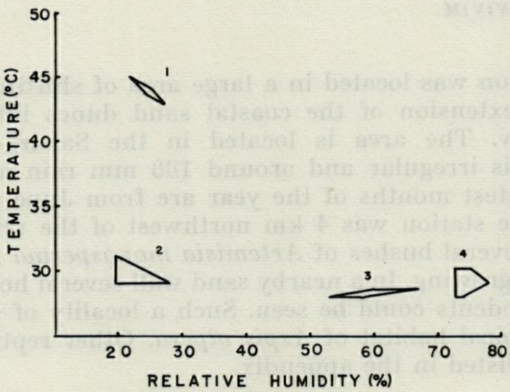

Fig. 2. — Thermohygrograms at station 1, Revivim, on June 1, 1961
1 — Air at 50 cm height.
2 — Burrow facing east, T-50 cm; RH-20 cm.
3 — Burrow facing noth, T-50 cm; RH-30 cm.
4 — Burrow under tin, T-50 cm; RH-50 cm (same as Fig. 1, D).

The second day of measurements was on a Hamseen (Scirocco) day. This was on June 1, 1961, a somewhat atypical day for that period as it was much hotter and drier then. The results of these measurements are given in Table 1, and some thermohygrograms are drawn in Figs. 1, and 2. Time-temperature curves are compared with those from other stations in Figs. 16, and 19. On the hamseen day there was very little variation in either temperature or humidity. The temperature was extremely high then, and the air was dry at all sites. The most favourable microclimate on such a day was in the burrow. The difference between the climates of the various burrows was mainly in humidity. The burrow facing east had a humidity range of 10-18 % inside, rather similar to the humidity range outside. This is possibly due to the fact it was facing the sun for longer periods during the day.

STATION 2. YOTVATA

This station was located in the Arava region which is the hottest and driest part of the Negev Desert. The amount of precipitation is about 54 mm. The area studied was at an elevation of 100 m, located 2 km east of the settlement, it is 40 km north of Eilath. This is an area of shifting sand dunes of Nubian paleozoic sandstone origin, blown down form an area northeast of there. The soil is of mixed sand and loess components, and of fine texture. The main plants there are *Halyxylon persicum, Salsola inermis, Suedea asphaltica* and *Zilla spinosa;* the coverage was about 30 %. This sand dune area is well inhabited by *Aspis cerastes*. All sites are described in the legend to the figures, the results given in Table 1, and the thermohygrograms in Figs. 3, 4 and 5. Time-temperature curves are drawn in Figs. 16, 17 and 21. Some of the animals pertinent to this study are listed in the appendix.

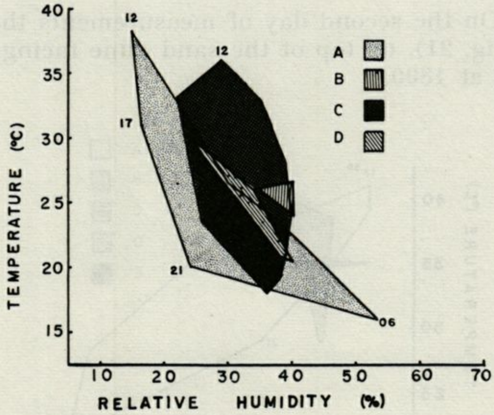

FIG. 3. — Thermohygrograms at station 2, Yotvata, on April 24/25, 1961.
A — Air at 50 cm height.
B — Burrow facing east, T-50 cm; RH-50 cm.
C — Burrow facing west, T-30 cm; RH-30 cm.
D — Reptile burrow facing east, T-10 cm; RH-10 cm.

Measurements were taken on April 24/25, May 16/17 and August 6/7, 1961. On the first day the sun reached sites 'A', 'B' and 'D' (Fig. 3) at 0630, and sunset occured at 1700. At site '2' (Fig. 16), a burrow facing east, the sun reached at 0600 and shade was at 1100. At site 'C' (Fig. 3) a burrow facing west, the sun reached at 0930 whereas shade was at 1800. The night was cool and several geckos *Stenodactylus (Ceramodactylus) doriae* were active

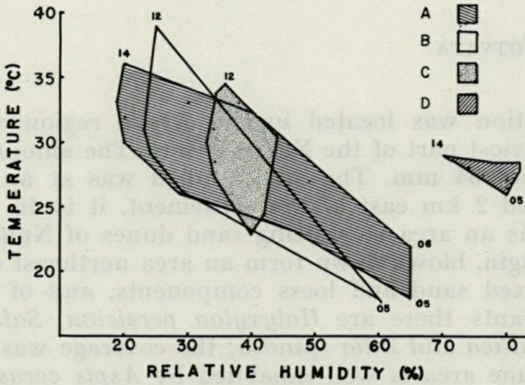

Fig. 4. — Thermohygrograms at station 2, Yotvata, on May 16/17, 1961.
A — Air at 50 cm height.
B — Ground, on surface of sand.
C — Burrow facing east, T-30 cm; RH-12 cm.
D — Burrow facing east, T-85 cm; RH-80 cm.

in the dunes. On the second day of measurements the sun reached burrow '2' (Fig. 21), on top of the sand dune facing west, at 1600 and shade fell at 1800.

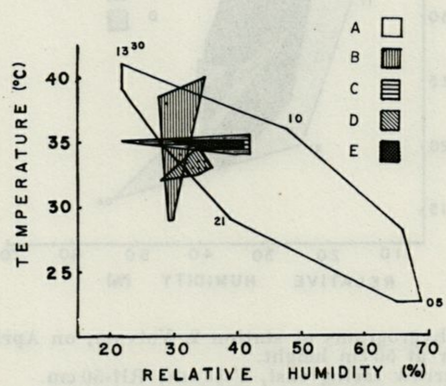

Fig. 5. — Thermohygrograms at station 2, Yotvata, on August 6/7, 1961.
A — Air at 50 cm height.
B — Burrow facing northeast, T-55 cm; RH-30 cm.
C — Burrow facing north, T-80 cm; RH-50 cm.
D — Burrow facing southeast, T-55 cm; RH-50 cm.
E — *Alsophylax* burrow facing east, T-70 cm; RH-45 cm.

The third day of measurements was on August 6/7, 1961. At 0400 it was still dark, sunrise being at 0500. At 1800 the shadow of the Yotvata Mountains fell on the dunes at the station, and darkness fell at 1900. During all hours of the day, including the hot midday, several animals were observed running on the surface of the hot ground in the sun. These were beetles, mainly tenebrionids, ants mainly *Cataglyphis* sp., and several *Mutillidae*. Also an interesting small black *Thysanura* sp. was running about in the midday sun. At 2100 at night several great beetles (a *Prionotheca* sp.), and some geckos *(S. doriae)* were found. At site 'D' (Fig. 5), a gecko *(Alsophylax blanfordi)* was caught when the thermistor was inserted into its burrow. In general, in that area a northern hot wind blows between 1300-1700 during summer.

On August 7/8, measurements were also taken at a station in the Yotvata Mountains. This is an area covered with stones and boulders, a typical habitat of *Echis colorata, Agama sinaita* and the spiny mouse *Accomys cahirinus.* Also found there is the small *Gerbillus nanus.* Temperature measurements at this section were taken with a glass thermometer (of ± 0.1 °C accuracy), whereas relative humidity was measured with hair hygrometers. The sites are described in Table 1, and results shown in Fig. 14.

On August 8/9 measurements were also taken at a site in Wadi Amusheimat. This dry creek is located south of Wadi Massri (Nakhal Shlomo), 6 km South of Eilath on the Red Sea. The area is typical for *A. sinaita* and *Uromastix ornatus.* Of rodents both *A. cahirinus* and *A. russatus* are found there. Sunrise occured in that area at 0500, but the sun reached the site at 0700, as the canyon opens towards southeast. The results are shown in Fig. 15.

Station 3. Ein Geddi

This station is located in an oasis on the Dead Sea at an elevation of (—) 360 m below sea level, and 30 m above the surface of the Dead Sea. The station was on a mountain slope covered with stones and great boulders. The vegetation in this oasis is typical for the tropical region, a relict of the Sudano-Decanian floral element. This includes several species of *Acacia* trees, *Salvadora persica, Moringa aptera* and others. The amount of precipitation is about 100 mm. This area is typical for *E. colorata,* other reptiles are listed in the appendix. The sites are described in the legend to the figures, and results shown in Figs. 6, 7 and 20.

On a typical warm spring day, on March 18/19, 1961, at 1100 hours the temperature in the hole inside a stone wall was 14 °C lower than that of air, and the relative humidity was 32 % higher there. At all other times on that day the difference between temperature and humidity in the other holes and in air, was less

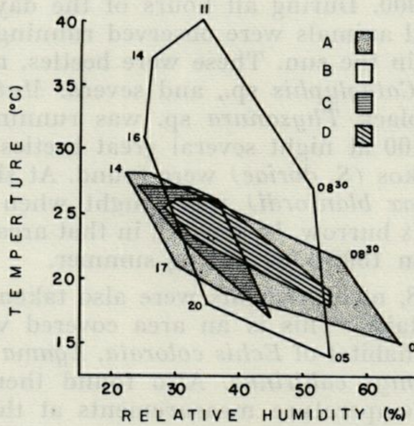

FIG. 6. — Thermohygrograms at station 3, Ein Geddi, on March 18/19, 1961.
A — Air at 150 cm height.
B — Ground.
C — Stone wall, 80 cm high.
D — Stone wall, 50 cm high.

extreme. Nevertheless, such holes provide important shelter from heat and dryness for the animals sheltering there.

Similar results were obtained in July, when the difference in climate between the stone wall and air was even smaller. At that time of the year such places would seem to provide less adequate shelter for the animals to live in them. In such hiding places, *E. colorata, A. cahirinus* and *A. russatus,* may be hiding during

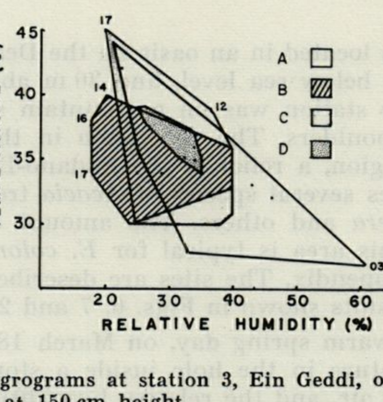

FIG. 7. — Thermohygrograms at station 3, Ein Geddi, on July 10/11, 1961.
A — Air at 150 cm height.
B — Ground, shade of rock.
C — Under stone, 14 × 15 × 50 cm.
D — *Accomys* burrow under rock, T-30 cm; RH-30 cm.

the day, or at least the hotter part of the day. The temperature there may be very close to the extreme temperature limit tolerated by such animals (42 °C), and to extreme dryness (25 %) that can be tolerated for any length of time. Finally, it is interesting to note that the weather on such typical summer day as July 10, 1961 (as measured in air), was hotter than on March 19, but the humidity was much the same on both occasions.

STATION 4. HALUTZA

This station was located some 20 km east of station 1, and 15 km south of Beer Sheva. This is the northern limit of distribution of *A. vipera,* in an area that is essentially an extension of the same sand dune complex described for station 1. Measurements were taken on two days : June 29, and July 19, 1961. The sites are described in the legends, and, some of the thermohygrograms are shown in Fig. 8, and the time-temperature curves given in Fig. 18.

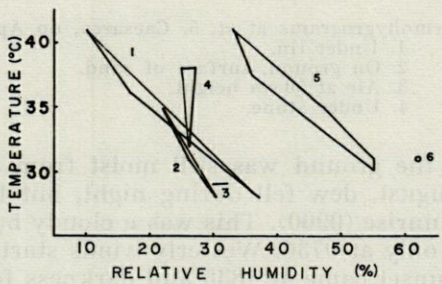

FIG. 8. — Thermohygrograms at station 4, Halutza, on June 29 and July 19, 1961.
1. On surface of ground (July).
2. In burrow, 45 cm deep (July).
3. In burrow, T-70 cm; RH-45 cm (July).
4. Under tin (June).
5. In burrow, T-60 cm; RH-30 cm (June).
6. In burrow, T-50 cm; RH-40 cm (June).

The microclimates measured in that station were intermediate in character between desert and mediterranean types. The temperature and humidity ranges were very small in the burrows, and great in air as is the case with all desert stations, but the humidity was somewhat higher.

Station 5. Caesarea

This station is in a sand dune area 2 km east of the settlement, in the coastal plains. Both this and the following station were chosen for comparative reasons, to compare the desert habitats with similar such habitats in the mediterranean region; Caesarea in the north and Holon in the centre. The measurements were taken on April 2, on June 2 (a hamseen day), and on August 16/17, 1961.

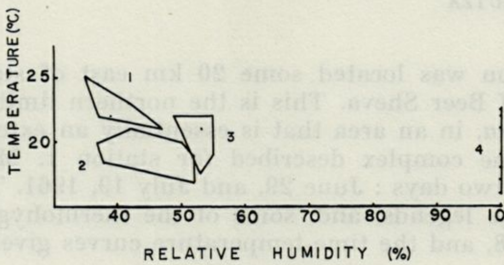

Fig. 9. — Thermohygrograms at st. 5, Caesarea, on April 2, 1961.
1. Under tin.
2. On ground, surface of sand.
3. Air at 50 cm height.
4. Under stone.

On the first day, the ground was still moist from previous rains. On the day in August, dew fell during night, but had evaporated four hours after sunrise (0900). This was a cloudy but hot day, and the sun appeared only at 0730. Westerly winds started at 1400 and lasted till 1630. Sunset came at 1830 and darkness fell at 1900, but

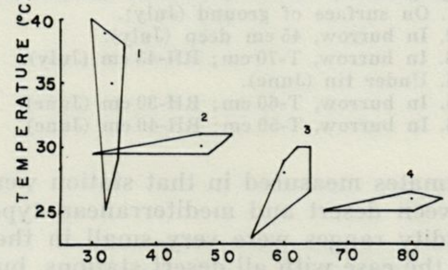

Fig. 10. — Thermohygrograms at station 5, Caesarea, on June 2, 1961.
1. Ground.
2. Air at 50 cm height.
3. Under stone.
4. In burrow, T-50 cm; RH-50 cm.

no activity occured on that night. All sites are described in the legends to figures, the thermohygrograms are given in Figs. 9, 10 and 11, and some time-temperature curves given in Figs. 16, 17 and 19. The ranges can be compared with those of other stations in Table 1.

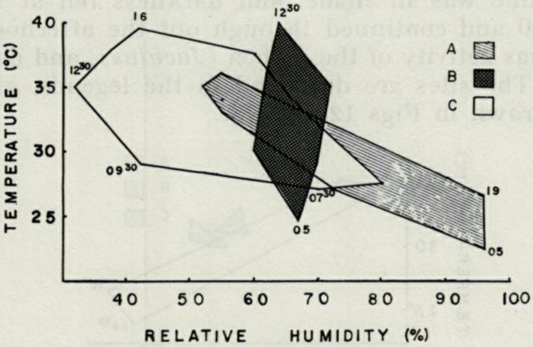

Fig. 11. — Thermohygrograms at station 5, Caesarea, on August 16/17, 1961.
A — Air at 50 cm height.
B — Ground.
C — Under stone.

Station 6. Holon

This station was located in the Rishon-Le-Zion sand dune area south of Holon. These shifting sand dunes are very similar in nature to the ones described for stations, 1, 2, 4 and 5, and were

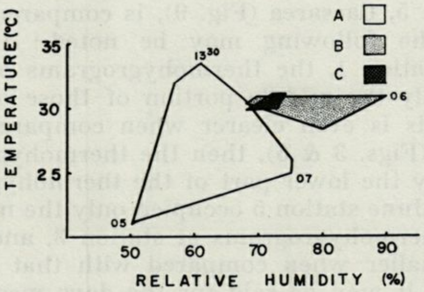

Fig. 12. — Thermohygrograms at station 6, Holon, on July 31, 1961.
A — Air at 50 cm height.
B — Burrow facing east, T-40 cm; RH-10 cm.
C — Burrow facing north, T-50 cm; RH-10 cm.

chosen to compare with those, the station being in the southern part of the coastal plains.

Measurements were taken on two days : July 31 and August 13, 1961. On the first day the sun reached the site at 0500 except at site ' 1 ' (Fig. 17) where it reached only ot 0800. At 1630 the eastern part of the dune was in shade, and darkness fell at 1830. Wind started at 1100 and continued through out the afternoon. At both nights there was activity of the Jerboa *(Jaculus)*, and dew fell later in the night. The sites are described in the legends, and thermohygrograms drawn in Figs 12 and 13.

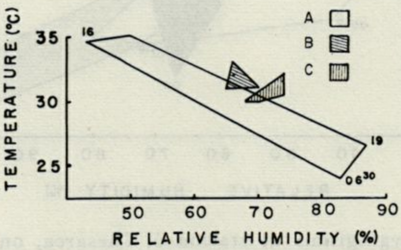

Fig. 13. — Thermohygrograms at station 6, Holon, on August 13, 1961.
A — Air at 50 cm height.
B — Burrow facing east, T-40 cm; RH-10 cm.
C — Burrow facing south, T-50 cm; RH-10 cm.

DISCUSSION

Comparing thermohygrograms of some stations

When station 5, Caesarea (Fig. 9), is compared with the three desert stations the following may be noted : In March when compared with station 1, the thermohygrograms obtained for station 5, occupy only the middle portion of those of station 1 (see Figs. 1 & 9). This is even clearer when compared with stations 2 and 3 in April (Figs. 3 & 6), then the thermohygrograms at station 5 occupy only the lower part of the thermohygrograms at the other stations. In June station 5 occupied only the middle and lower portions of the thermohygrograms at station 3, and the variability was definitely smaller when compared with that station (Figs. 7 & 10). In general it may be said for the days measured, all three desert stations have a definite larger temperature and humidity range of air than at the mediterranean station. This is at variance with observations by Chapman et al. (1926) who found in their measurements in Minnesota sand dunes that the extreme variations in temperature and humidity there were essentially like those characteristic of deserts.

When now station 2, Yotvata (Fig. 3) is compared with station 1 (Fig. 1) in spring, the thermohygrograms indicate a hotter and drier environment at station 2, and the humidity reached higher levels at station 1. The lower humidity range was however rather similar. When station 2 (Fig. 3), is compared with station 3, Ein Geddi (Fig. 6) in spring, the temperature is similar, but it is drier in Yotvata, similarly the range and variability are somewhat greater there.

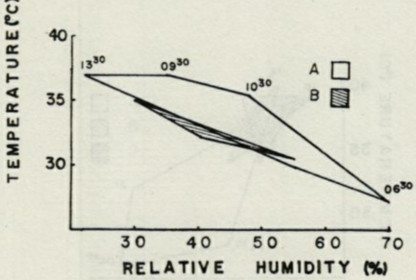

Fig. 14. — Thermohygrograms at station 7, Yotvata Mountains, on August 7/8, 1961.

A — Air at 50 cm height.
B — Burrow facing north, T-75 cm; RH-65 cm.

When thermohygrograms of station 3, Ein Geddi (Fig. 6), are compared with those of station 1, Revivim (Fig. 1), in spring, the humidtiy range was similar though it was hotter and less variable in Ein Geddi. During measurements in spring, Revivim had a higher minimum humidity and a lower maximum temperature that at both other stations. Ein Geddi had the highest maximum R.H., and the lowest minimum temperature, followed by Revivim and Yotvata respectively. During summer, conditions were similar at all three desert stations with a higher humidity at Ein Geddi (Figs. 2, 5 & 7).

Comparing time-temperature curves

All stations in sand dune areas show similar patterns in one respect : high extreme temperatures on the surface of the sand with a sharp depression towards the interior (Williams, 1923; Sinclair, 1922; See also Kachkarov & Korovine, 1942; Buxton, 1924, 1932). Even when the thermometer is covered by only a small layer of sand to shield it from direct sun, a significant depression of temperature occurs. A depression in temperature may be noted also in burrows under a tin, or under stones, rocks or even under a bush and in cracks in sand wall, etc. The significance of such refuges to the animal, is obvious from the temperature curves given in Figs 16-21. The holes in particular are a remarkably efficient insulator from high temperatures. The significance of the well known habits of some rodents, to close the entrance to the burrow after their retreat, is not obvious from the data on temperature and humidity prevailing inside, although it may presumably be explained on other grounds. In a place such as Ein Geddi, stones and rocks provide the main refuge, whereas in sand dunes burrows take their place.

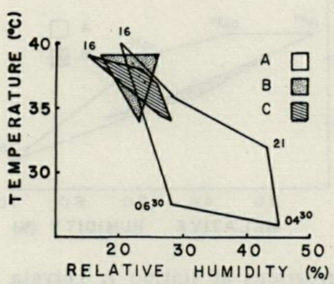

Fig. 15. — Thermohygrograms at station 8, Wadi Amusheimat, on August 8/9, 1961.

A — Air at 50 cm height.
B — Burrow facing east, under rock.
C — Burrow facing south.

To illustrate such a case : a hole occupied by *Uromastix aegyptia* at the entrance of Wadi Timna, will be described. This canyon is located about 30 km north of Eilath. The hard soil is of hammada type covered by small granite stones. The vegetation consists of *Haloxylon articulatum* and *Acacia tortilis*. Measurements were taken on May 17, and August 8, 1961. At 0730 on May 17, a minimum temperature of 25 °C was recorded at a depth of 150 cm in that burrow, and at 1330 hours a maximum of 28 °C. The R.H. at 100 cm deep was 72 %. The temperature outside at that time was 36 °C and the humidity 20 %. These results are rather similar to the ones found in a hole 85 cm deep at Yotvata sand dunes one day earlier (where at 1400, the temperature was 29 °C and the R.H. 70 %, see Fig. 4).

On August 8, at 0900 hours, measurements in the same burrow at a depth of 125 cm, have indicated a temperature of 37 °C as compared with 33 °C in the air 50 cm high, and 35 °C on ground.

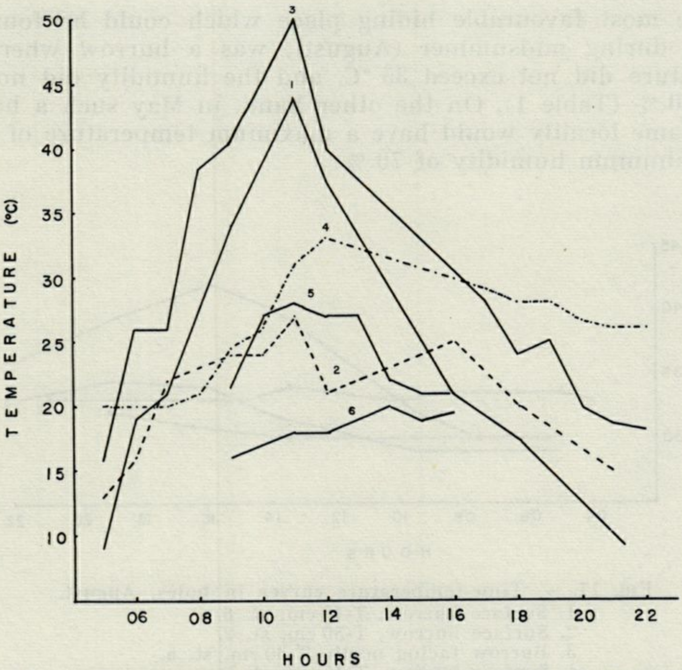

FIG. 16. — Time-temperature curves at stations 1, 2 and 5, in spring.
1. On ground st. 2.
2. Rodent's burrow facing east, T-20 cm, st. 2, April.
3. On ground, st. 1, March.
4. Burrow facing north, T-15 cm, st. 1, March.
5. On ground, st. 5, March.
6. Burrow, T-15 cm, st. 5, March.

The humidity at a depth of 100 cm was 35 % as compared with 30 % in the air. These measurements, taken 4 hours after sunrise on a midsummer day, indicate the restricted capacity for heat dissipation from the burrow during a hot summer night. This makes it a rather poor refuge during the day, but it is hard to imagine any better ones than this burrow. Animals will therefore have to contend with such refuges, and survive long periods at such high temperatures and low humidities.

THE SIGNIFICANCE OF HIDING PLACES IN THE DESERT

What is the most typical quality of desert animals ? It is probably their ability to live in places where there is an extreme shortage of water, and where they are exposed for long periods of the year to high temperatures and low humidities.

The most favourable hiding place which could be found at Yotvata during midsummer (August), was a burrow where the temperature did not exceed 35 °C, and the humidity did not fall below 30 % (Table 1). On the other hand, in May such a burrow in the same locality would have a maximum temperature of 29 °C and a minimum humidity of 70 %.

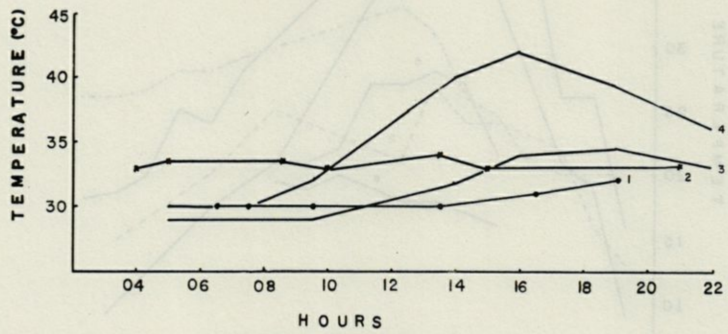

FIG. 17. — Time-temperature curves in holes, August.
1. Surface burrow, T-40 cm, st. 6.
2. Surface burrow, T-50 cm, st. 2.
3. Burrow facing north, T-30 cm, st. 5.
4. Surface burrow, T-40 cm, st. 5.

When a typical burrow at Caesarea, is compared with a similar one in Yotvata sand dunes, the main difference observed is one of humidity. The temperature in a typical Yotvata burrow ranged between 27-45 °C, and the humidity between 22-42 %, whereas at Caesarea the temperature range in a typical burrow was 27-42 °C, but the humidity ranged from 30-80 % (see Table 1). This is a strikingly higher humidity. An animal that has as its best opportunity a burrow such as the one at Yotvata, will eventually lose more water than a similar individual living in a burrow of the kind observed in Caesarea (for discussion see SCHMIDT-NIELSEN, 1958).

To illustrate this point further a second example will be cited : A burrow in Holon sand dunes as measured on an August day will be compared with a similar burrow in Yotvata sand dunes at the same month. The temperature in the Holon burrow ranged between 31-33 °C, and the R.H. between 65-70 %, as compared with 34.5 - 35 °C and 30-41 % R.H. inside the Yotvata burrow. Both burrows were probably *Gerbillus* sp. dens, and both have a rather small and somewhat similar temperature range but differ greatly in humidity.

Table 1

Temperature and humidity ranges

Station Nº	Locality	Dates in 1961	Sites	Temperature Max.	Temperature Min.	Temperature Absol. Range	Relative Humidity Max.	Relative Humidity Min.	Relative Humidity Absol. Range
1	Revivim	March 18/19	A-Air	30.0	10.0	20.0	80	14	66
			B-Ground	39.0	10.0	29.0	90	25	65
			C-Hole, 40	21.0	14.0	7.0	62	30	32
			D-Hole, 50	20.5	16.0	4.5	100	70	30
2	Yotvata	April 24/25	A-Air	38.0	16.0	22.0	53	15	38
			D-Hole, 10	30.0	20.5	9.5	40	24	16
			C-Hole, 30	36.0	18.0	18.0	40	22	18
			B-Hole, 50	26.0	24.0	2.0	40	34	6
		May 16/17	A-Air	36.0	18.0	18.0	65	19	46
			B-Ground	39.0	18.0	21.0	60	23	37
			C-Hole, 30	34.5	23.0	11.5	44	33	11
			D-Hole, 85	29.0	26.0	3.0	82	70	12
		August 6-8	A-Air	41.0	22.5	18.5	69	22	47
			C-Hole, N	34.5	32.0	2.5	36	28	8
			E-Hole, E	35.0	34.5	0.5	41	30	9
			D-Hole, SE	35.5	34.0	1.5	42	22	20
			B-Hole, NE	40.0	29.0	11.0	35	28	7
3	Ein Geddi	March 19/20	A-Air	28.0	15.0	13.0	65	22	43
			B-Ground	40.0	14.0	26.0	54	25	29
			D-Stone wall, 50	26.0	18.0	8.0	52	29	23
			C-Stone wall, 80	27.0	17.0	10.0	45	31	14
		July 10/11	A-Air	44.0	27.0	17.0	61	21	40
			B-Ground	40.0	27.0	13.0	40	18	22
			C-Stone	45.0	30.0	15.0	40	25	15
			D-Hole	39.0	34.0	5.0	35	25	10
5	Caesarea	April 2/3	3-Air	22.0	17.5	4.5	55	49	6
			2-Ground	21.0	17.0	4.0	52	37	15
			4-Stone	22.5	16.0	6.5	100	100	0
			1-Tin	25.0	21.0	4.0	47	35	12
		June 2	2-Air	31.0	29.5	1.5	52	30	22
			1-Ground	40.0	25.0	15.0	35	30	5
			3-Stone	30.0	23.0	7.0	64	55	9
			4-Hole, 50	26.5	25.0	1.5	85	66	19
		August 16/17	A-Air	36.0	22.5	13.5	95	52	43
			B-Ground	40.0	24.5	15.5	72	60	12
			C-Stone	39.5	27.0	12.5	80	32	48

Max. - Maximum ; Min. - Minimum ; Absol. - Absolute.

Letters preceding sites refer to letters in appropriate figures.

Numbers following sites refer to depth of measurement, and letters following sites refer to aspect of opening.

Factors influencing the microclimate of a burrow include its depth, the degree of ventilation within it, the amount of moisture in the surrounding ground, and the aspect. The inclination of the surface or the angle between the sun's rays and the ground, are factors affecting the amount of heat absorbed by the ground. Undoubtedly the degree to which vegetation covers the ground is also important; and finally, wind, cloud and other meteorological factors that affect the macroclimate, will also have some effect on microclimate.

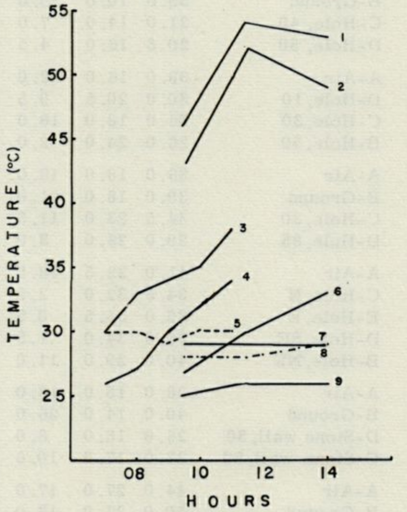

FIG. 18. — Time-temperature curves at station 4, Halutza.
1. In sand (July).
2. On sand (July).
3. Under tin (June).
4. In crack in sand wall (June).
5. On surface of sand, shade (June).
6. Surface burrow, T-70 cm (July).
7. Burrow facing east, T-10 cm (July).
8. Burrow facing south, T-45 cm (July).
9. Burrow facing north, T-35 cm (July).

It is possible that an animal inhabiting a system of burrows would shift from one part of the dune to the other, in order to find the most favourable conditions. In that way it would take advantage of differences due to aspect or ventilation.

COMPARISON WITH SIMILAR STUDIES IN OTHER DESERTS

Data on microclimates in other deserts are known already from earlier literature (see reviews in KASHKAROV & KOROVINE, 1942;

Buxton, 1924, 1932). The conditions in Yotvata compare very well with those found in the Sonora Desert (Schmidt-Nielsen & Schmidt-Nielsen, 1950; Vorhies, 1945). Measurements made under stone have indicated a temperature range between 25-45 °C there (Warburg, 1965*a*). The summer in Arizona is not completely dry as there are a few rainy days, and about half the annual precipitation falls then. For this reason somewhat higher humidities were observed there, ranging under a stone between 15-78 % R.H.

The mediterranean stations have also high maximum humidities, but the minimum humidity rarely drops below 40 % (except on a hamseen day). In the three desert stations even after a rainy period in spring, the humidity drops to low values (14 % at Revivim, 15 % at Yotvata, and 22 % at Ein Geddi station), such as are found in Caesarea only on a hamseen day.

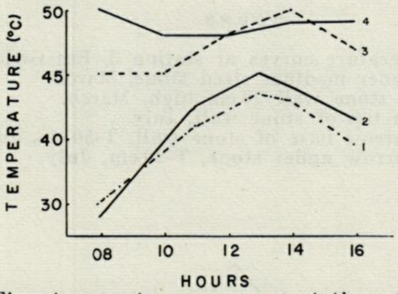

Fig. 19. — Time-temperature curves at stations 1 and 5, June.
1. On ground, station 5.
2. Under tin, station 5.
3. Under tin, station 1.
4. On ground, station 1.

The distribution of vipers in the Negev

The microclimate is described in the habitats of three of the four species of *Viperidae* that occur in the Negev. These studies were conducted during the hotter and drier half of the year when snakes are most active. The two species of *Aspis* occur only in the desert on sand dunes, and not on other types of soil. On the other hand they are absent from sand dune areas in the northern half of the country along the coastal plains of the mediterranean region which appear to be suitable habitat. The continuous area of dunes extending westwards and northwestwards from the northern Negev, would enable the extension of *A. vipera* to that region. However the fact that this species does not occur in the sandy coastal plains

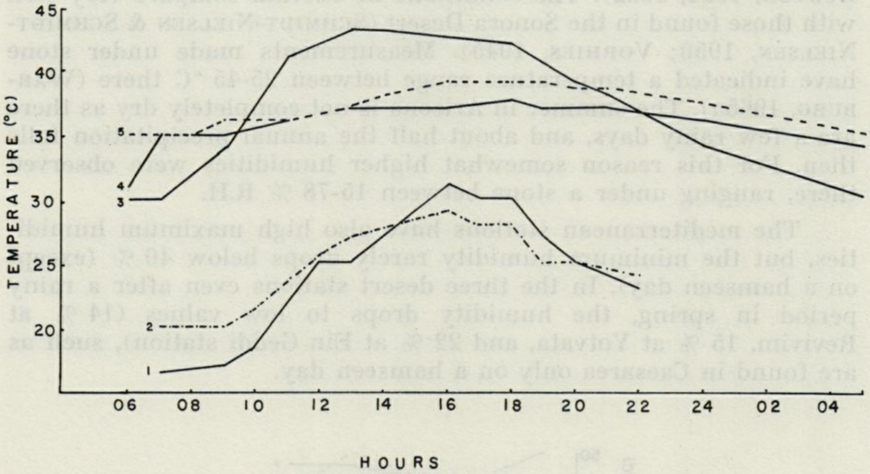

FIG. 20. — Time-temperature curves at station 3, Ein Geddi, March and June.
1. Under medium sized stone, March.
2. In stone wall 20 cm high, March.
3. On top of stone wall, July.
4. Burrow base of stone wall, T-50 cm, July.
5. Burrow under stone, T-20 cm, July.

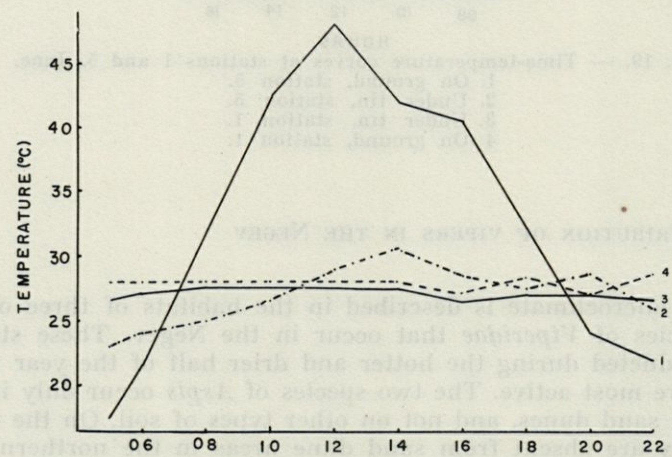

FIG. 21. — Time-temperature curves at station 2, Yotvata, May.
1. On surface of ground.
2. Burrow, T-20 cm.
3. Burrow, T-70 cm.
4. Burrow, T-45 cm.

of the north calls for a different explanation. It is possible that the lower maximum and mean temperatures, and the higher humidity in this area are the limiting factors. If this is so during the hotter half of the year when the measurements were taken, it is quite probable that during winter conditions would worsen for the snakes, and they would be unable to hibernate at such high humidities. The second species, *A. cerastes,* is limited to sand dune areas in the Arava, as there is no sand dune connection with the northern Negev.

The third species, *E. colorata,* occurs in rocky regions only, extending from the Arava through the Negev and the Judean Desert northward to the Jordan Valley, and into the Gilboa Mountains in the northern part of the country. This distribution is patchy and difficult to explain. The microclimatic conditions in the latter region remain to be studied before any suggestion can be made regarding the nature of this distribution pattern.

SUMMARY

1) The main difference between the microclimates in the desert and in the coastal region are described. In the desert the temperature and humidity range more widely, and in the coastal region the humidity is rarely as low as in the desert.

2) The difference in microclimates among the three desert stations is more in the relative humidity than in the temperature. At Ein Geddi (St. 3), the relative humidity is somewhat higher than at the other stations, there is also less variability in the climate. The most extreme conditions occur at Yotvata (st. 2).

3) The holes with the smallest temperature ranges have the highest minimum temperature and the lowest maximum humidity. This may be partly due to factors summarized under (4).

4) The process of absorbing and dissipating heat is slow in holes, and therefore the temperature range is small. The relative humidity is dependent on depth, degree of ventilation, and the form of burrow as well as the amount of moisture in the soil.

5) The microclimates in the burrows differ greatly (especially in temperature) from those of ground and air.

6) The distribution of *A. vipera, A. cerastes* and *E. colorata,* appears to be determined mainly by the availability of a suitable substrate, and only then by suitable microclimate.

RÉSUMÉ

1. L'auteur décrit les principales différences entre les microclimats du désert et de la région côtière. Dans le désert, la température et l'humidité varient plus largement, dans la région côtière, l'humidité est rarement aussi basse que dans le désert.

2. La différence entre les microclimats des trois stations désertiques porte davantage sur l'humidité relative que sur la température. A Ein Geddi (station 3), l'humidité relative est un peu plus élevée que dans les autres stations, il y a aussi des variations climatiques plus faibles. Les conditions les plus extrêmes sont celles de Yotvata (station 2).

3. Les trous où les variations de température sont les plus faibles ont le plus haut minimum de température et le plus bas maximum d'humidité. Ceci est dû en partie aux facteurs énumérés ci-dessous (4) :

4. Le processus d'absorption et de dissipation de la chaleur est lent dans les trous, et en conséquence la variation de température est faible. L'humidité relative dépend de la profondeur, de l'importance de l'aération, de la forme du terrier ainsi que de la quantité de moisissure contenue dans le sol.

5. Les microclimats des terriers diffèrent beaucoup (surtout du point de vue thermique) de ceux du sol et de l'air.

6. La distribution de *A. vipera, A. cerastes* et *E. colorata* semble dépendre principalement de la présence d'un substrat adéquat et secondairement d'un microclimat convenable.

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Appendix

Faunal List of Reptiles found at the Desert Stations

Locality	Revivim st. 1	Yotvata st. 2	Ein Geddi st. 3
Gekkonidae			
Stenodactylus stenodactylus	+	+	
S. (Ceramodactylus) doriae		+	
Ptyodactylus hasselquistii			+
Alsophylax blanfordii		+	
Tropiocolotes steudneri			+
Scincidae			
Chalcides ocellatus			+
C. sepsoides	+	+	
Scincus scincus		+	
Varanidae			
Varanus griseus	+	+	
Lacertidae			
Acanthodactylus boskianus	+	+	+
A. pardalis	+		
A. scutellatus	+		
Eremias olivieri	+	+	
E. gutullata	+		+
Chameleonidae			
Chameleo chameleon	+		
Agamidae			
Agama pallida	+		
A. savignyi	+		
A. sinaita			+
A. stellio brachydactyla	+		
Uromastix aegyptia		+	
Typhlopidae			
Typhlops simoni	+		+
Leptotyphlopidae			
Leptotyphlops phillipsi			+
Colubridae			
Eirenis lineomaculata	+		
Coluber rogersi	+		
C. rhodorachis			+
C. elegantissimus		+	
Spalerosophis cliffordi	+	+	+
Psammophis schokari	+		
Malpolon moilensis		+	
Telescopus dhara	+		
T. hoogstrali	+		
Lytorhynchus diadema		+	
Elapidae			
Atractaspis engaddensis		+	+
Walterinesia aegyptia	+		
Viperidae			
Aspis vipera	+		
Aspis cerastes		+	
Echis colorata			+