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ZOOLOGY

Thermal Ecology and Activity of the Sand Fish Lizard, *Scincus mitranus* (Scincidae) in Central Arabia

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Abstract. Thermal ecology and activity of *Scincus mitranus* was investigated during winter and summer seasons. Emergence and basking behavior and seasonal activity were studied and analyzed. The lizard was active throughout the year except during cold spells of winter. However, it was found that during winter, daily activity was unimodal, which contrasted with the bimodal pattern during summer. Selected body temperature, critical minimum and maximum were studied and determined in the laboratory.

Introduction

Temperature is one of the most important factors in the ecology of reptiles, and most of their daily activities are affected through their responses to the thermal resources of the environment. Moreover, many workers have considered the problems of thermal ecology, thermoregulation and reptilian critical temperatures[1-15]. Substantial contributions can be attributed to the reviews of Cloudsley-Thompson [16, pp. 39-59], Heatwole [17], Avery [18, pp. 93-166] and Huey [19, pp. 25-91].

Most of the work has been done on diurnal lizards of the deserts of Australia [17;20], and the Kalahari desert [7]. Few studies have been undertaken on the desert lizards of

Arabia;the most significant of these are on the ecology of lowland lizards [9] and on general aspects of the daily and seasonal activities and on the thermal ecology of the sand lizards. *Acanthodactylus schmidti* and *A . boskianus* in the central region of Saudi Arabia [11].

In Arabia the genus *Scincus* is represented by three species. One of which is the Arabian sand fish, *Scincus mitranus*. It is found throughout the sand dunes of Arabia [21] and widely distributed [22, p. 135] with additional populations in north-eastern Yemen, southern Oman, United Arab Emirates and Kuwait [23].

In the present study, some aspects of the daily and seasonal activities and of the thermal ecology of *S. mitranus* are investigated to provide information on temperature regulation and behavioral adaptations of this species to its harsh desert environment.

Materials and Methods

The study was carried out on an area about 60 km north of Riyadh, in Irq Banban, north-east of King Khalid International Airport. The investigation included observation on the daily and seasonal activities of the skink through binoculars (Field 6.2, Size 9 x 63), from 6 am to 6 pm for a period of 10 consecutive days once in spring and once in summer. Air and soil temperatures were recorded using a Shultheis thermometer. Morning emergence and all observable activities of the lizards were recorded every hour. A log book was maintained, recording the number of skinks that emerged and the last ones that disappeared in the sand. Temperature parameters were recorded hourly.

The selected body temperature (SBT) of *S. mitranus* was measured in the laboratory using a thermal gradient chamber. The chamber consisted of a metal box measuring (200 x 18 x 80 cm) and contained an even layer of sand 5 cm deep. The chamber was heated and cooled from below to substratum temperatures of 10 to 45°C (room temperature ranged 20-25°C). The lizards were not fed during the experiments, but water was provided *ad libitum*. Overhead lighting was supplied by a 250 W electric lamp with a light dark cycle of 12:12 hrs. Body temperatures were recorded using YSI model 511 tissue implantation thermistor probes inserted into the cloaca of the lizards. A YSI model 44 telethermometer and a chart recorder were used in conjunction with the thermistor probes. The animals were allowed to adjust in the chamber for 24 hrs before recording of body temperature commenced, after which it was continued for 3 days and nights. Mean body temperature was calculated from the continuous records of data obtained.

The critical minimum temperature (CTMin) was measured in a cooling chamber (60 x 50 x 40 cm) whose bottom was covered with a layer of ice 15-20 cm deep. With a thermistor inserted, animals were placed into plastic containers and gradually introduced into the cooling chamber. The CTMin was presumed to be reached when the animal could not right itself when it was overturned on its back. The critical maximum temperature (CTMax) was measured in the same chamber. A layer of sand 2-3 cm deep was provided and warmed by a heater from below and from above by a 250 W lamp 40 cm above the sand surface. The CTMax was assumed to to have been reached when the animal could not right itself when turned on its back.

Results

Morning emergence

In summer, the animals emerged from their burrows 20-30 minutes after sunrise when the air temperature was 25-27°C, and soil temperature 26-29°C. At first just the head appeared being directed towards the rising sun. Skinks stay in this position heating the head for 10-20 minutes. They then come out of the sand to bask for a few minutes before moving around looking for food. Lizards then move to areas of fine sand around the bases of plants to bury themselves. However, at 1700 hours in the afternoon, when the air and soil temperatures are 40 and 42°C, respectively, the animals re-emerge but faster than in the morning, and stay active near the shade of bushes. As the temperature drops with the advancing evening, they move further away before disappearing into their burrows 5-10 minutes before sunset.

During spring (March), which is a time of low temperatures and rain, the animals only emerged at midday when both air and soil temperatures ranged from 25-27°C and 29-33°C, respectively, using the same emergence procedure before basking and moving off. In winter especially during January no animals were seen.

Typically the animal usually basks for an hour, first taking heat heliothermically and then thigmothermically by spreading its belly on the sand for some minutes. It keeps shuttling between the two methods till it reaches the optimum temperature to carry on all other activities. The real activities of *S. mitranus* occur when the air and soil temperatures reach 29-30°C and 29-31°C, respectively. The animals then stay active till these temperatures reach 37-39°C and 43-45°C respectively. At this point the animals were seen raising their bodies on their limbs off the ground to avoid such high temperatures.

Daily and seasonal activity

Lizards were seen active all year round except during the cold periods of winter when the animals were neither sighted nor collected. The winter mean temperature was 13.1°C for the study period. The animals stay inside the sand during these times, especially if it is raining, and emerged only after the wet sand had dried.

During the summer, on the other hand, daily activities were bimodal. The skinks start activity 40-60 minutes after sunrise when air temperature was 24°C and that of the soil 25°C. The highest rate of activity occurred between 0700 and 0800 hours, when the air and soil temperatures were 29-34°C and 30°C, respectively. By 0900 hours, all the lizards disappeared in the sand at the cooler shades of the plant bases. The air and soil temperatures were 37-40°C and 40-46°C, respectively. The second period of daily activity occurred in the afternoon around 1700-1730 hours when the air and soil temperatures were 40-43°C and 41-46°C respectively. The number of active lizards was much smaller during the latter period. With the approaching sunset, and the temperature falling to 38-40°C, the lizards expanded their area of activities (Fig.1).

During the spring, especially over the early days of the season, when both of the air and soil temperatures were 11-12°C and 7-25°C, respectively and the weather was still cold and rainy, no skinks emerged. After the fifth day of observation, the rains stopped and the air and sand temperatures reached about 20-23°C and 30-35°C respectively. *S. mitranus* then exhibited unimodal activity around midday (Fig.2). A single specimen was collected during the rain and even that was only possible by digging the animal out from around the base of a shrub, where the air and sand temperatures were around 20°C.

Temperature regulation

Similar to many other reptiles, *S. mitranus* gained heat energy directly from the sun (heliothermy) by two methods, posturing and shuttling heliothermy, to reach its activity temperature, before its main daily activities. Morning emergence started with the protruding of its head only for 10-20 minutes followed by the rest of the body facing the sun. Hence, the animal prefers sand slopes that face south-east toward the sun. During the afternoon session of activities, the animal emerged from the sand at a time where air and soil temperatures (28-32°C and 27-33°C, respectively) are high enough to provide it with its activity temperature but not so high to prevent activity.

In winter, heliothermy is achieved by longer posturing periods exceeding the usual 30 minutes and all activities occur at midday, when the air and soil temperatures were 26°C and 28°C, respectively. During both summer and winter, the body temperature of *S. mitranus* was higher than both air and substrate temperatures.

The correlation between body temperature and air temperature was highly significant during both summer ($P<0.001$, $n=86$) and winter ($P<0.001$, $n=72$)(Fig.3). Moreover, the correlation between the body temperature and that of the ground temperature was also highly significant during the summer ($P<0.001$, $n=86$) as well as during winter ($P<0.001$, $n=72$) (Fig.4).

Selected Body Temperature (SBT)

The eccritic temperature (selected body temperature in the field) of *S. mitranus* was lower during winter and spring than during summer and autumn. The range of the eccritic temperature during winter was 25-42°C with a mean body temperature of 34.6°C and during summer the range was 27-44°C and a mean body temperature of 36.7°C (Fig.5).

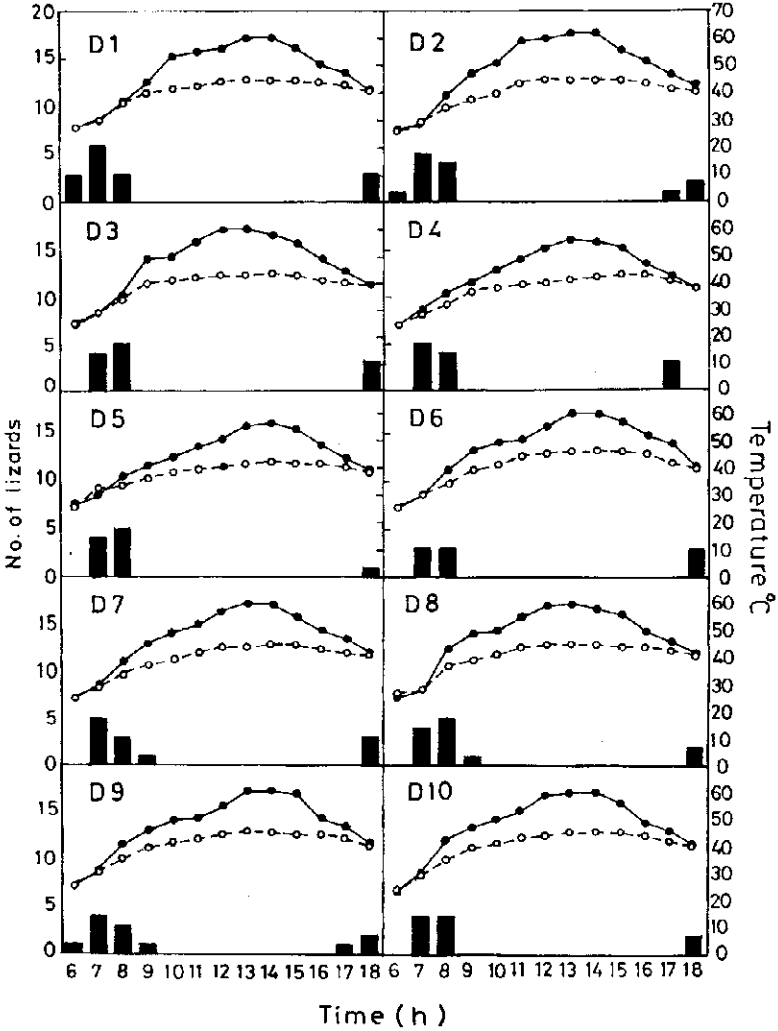

Fig. 1. Number of active *S. mitranus* (bars), air temperature (-o-) and ground temperature (-•-), during ten days of summer.

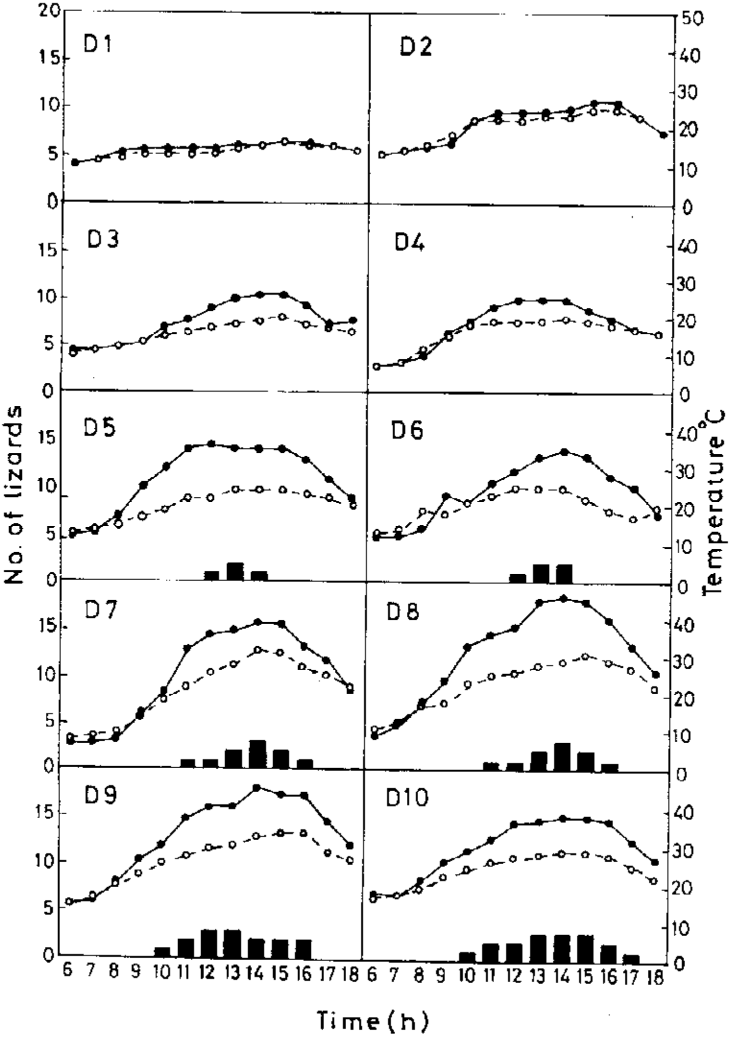

Fig. 2. Number of active *S. mitranus* (bars), air temperature (-o-) and ground temperature (-•-), during ten days of spring.

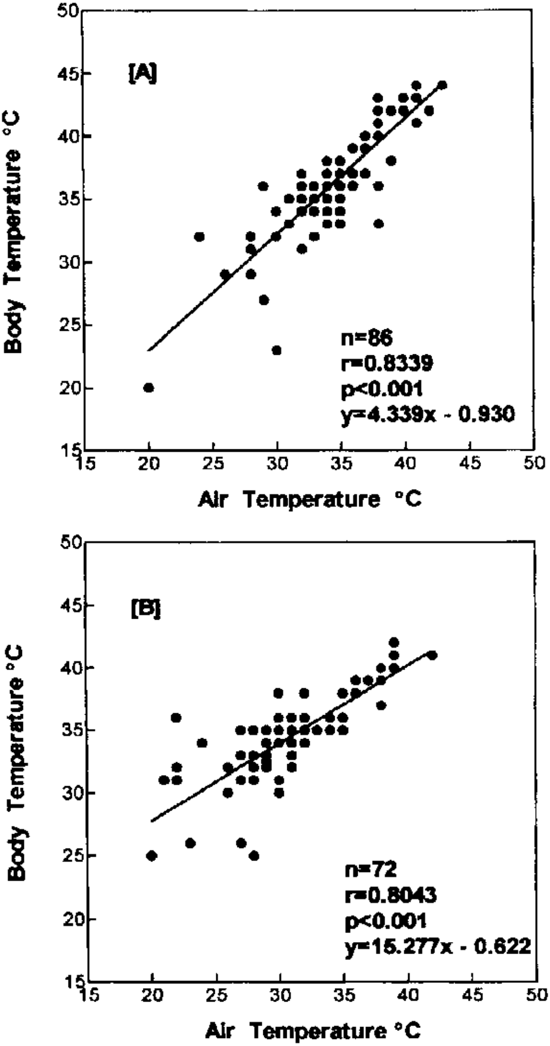

Fig. 3. Relationship of body temperature to air temperature of *S. mitranus*, (A) during summer, (B) during spring, in the study area. Solid line is the regression line.

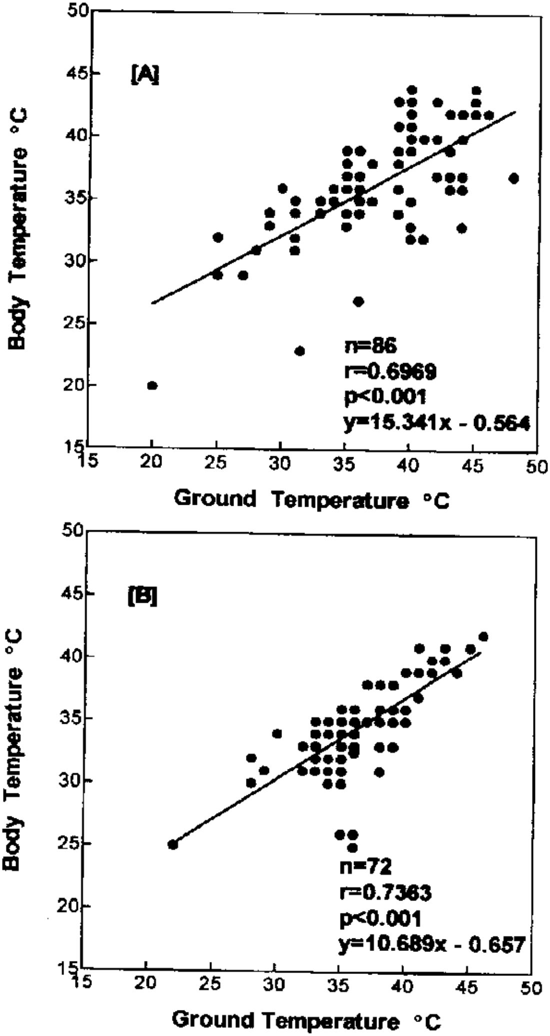

Fig. 4. Relationship of body temperature to ground temperature of *S. mitranus*, (A) during summer, (B) during spring, in the study area. Solid line is the regression line.

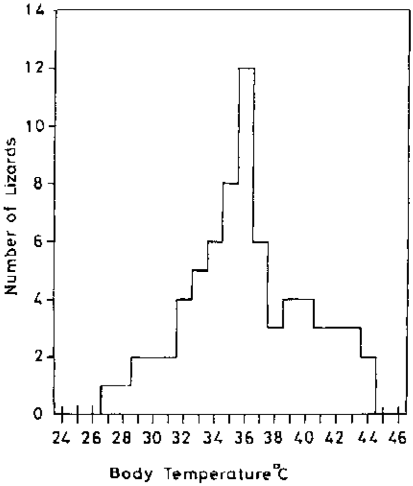

Fig. 5. Frequency distribution of body temperature of *S. mitranus* (male and female) collected in the study area during summer.

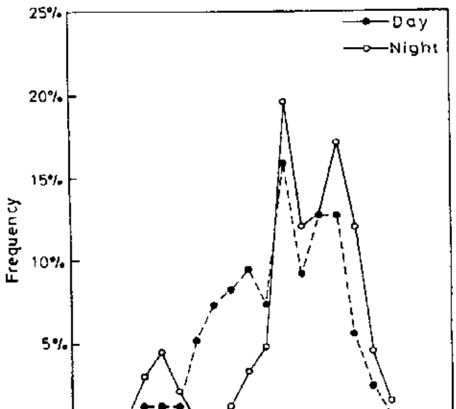

Fig. 6. Frequency distribution of the selected body temperature in the thermal gradient during day and night hours of *S. mitranus*.

Moreover, the laboratory observations on SBT approximately match the eccritic temperature of *S. mitranus*. During the day they were observed to select temperatures between 26-40°C with a mean body temperature of 34.4°C. While in the dark period, they selected temperatures between 24-40°C with a mean body temperature of 35°C (Fig.6).

Critical Thermal Minimum (CTMin)

The animals, once put into the test chamber, started to move around looking for a warm place, by diving and burying their heads in the sand, or by going to a corner to escape the adverse environment. This continued for a period of 13-25 minutes before the animal ceased to move. If then the lizard was turned-over, it was unable to right itself. It was immediately removed from the test chamber to be warmed up to reach its normal temperature. The CTMin was determined to be 13.1°C (Table 1).

Table 1. Calculation of the critical minimum temperature, critical maximum temperature, time needed to reach critical temperatures, body weight, snout-vent length and vent-tail length of the experimental animals

Critical minimum temperature (°C)		Time needed to reach CTMin. (min)		Critical maximum temperature (°C)		Time needed to reach CTMax (min)	
Range	Average	Range	Average	Range	Average	Range	Average
11-15	13.11	13-25	17.33	46-48	47.11	22-46	29.33

Table. [*Continued*]

Snout-vent length (mm)		Vent tail length (mm)		Body weight (g)		N
Range	Average	Range	Average	Range	Average	
90-120	109.4	35-75	62.22	20.17-44.80	33.35	9

Critical Thermal Maximum (CTMax)

During the first 15 minutes after introduction in the test chamber the lizards behaved normally. When temperature neared 44°C, they started to move very fast, trying to escape the adverse conditions. They used both fore and hind limbs to dig in the sand trying to reach the cooler layers, and at the same time used their limbs to lift their bodies off the hot sand. As time went by, their whole bodies especially the tails started trembling. Thereafter, they made involuntary movements and were panting heavily trying to reduce their high body temperature. As maximum tolerance was attained, the animals could not right themselves when turned over. CTMax was reached in 22-46 minutes and was determined to be 47.1°C (Table 1). The animals were then removed from the test chamber, wrapped in a moist cloth and air was blown over them to return them to their normal temperature.

Discussion

The present results show that the sand skink, *Scincus mitranus* is active almost all year round, except during the colder days of January and also disappears during rainy days. Emergence first occurs early in the morning, animals remaining for a considerable period with only their heads above the sand before completely coming out. This is similar to the behaviour of *Uma notata* [24] and to the "head basking" described for both *Acanthodactylus schmidti* and *A. boskianus* [11], as well as for agamid lizards [25]. The initial protrusion of the head could be a cautious strategy employed to avoid predators as the body remains fully submerged. Heating of the head could also be adaptive, as a means of spreading the heat to the rest of the body.

Once out of the sand, the skink seems to prefer posturing heliothermy where the temperature is low. However, later in the day, with the increasing temperature, it shifts to shuttling heliothermy which is also adopted in the afternoon period of activity. Moreover, thigmothermy is also used to reduce body temperature. The upper sand levels are scraped aside with the limbs and the animal's belly is placed in contact with the cooler layers below the surface.

Like other reptilian species in the study area, the skink appears and disappears several times during its daily activities. Most of this takes place in the morning, especially during summer. The morning period of activity is quite long (2-2½ hrs after the basking period) at a time when the ambient temperature is gradually rising. Insects, especially beetles which constitute the major part of the animal's food are abundant in the morning with declining numbers as the day progresses. Rising air and soil temperature at midday together with their continuation at high levels over the afternoon till 1700 hrs seem to restrict the movements of the skinks to shady areas around the shades of shrubs helping them to avoid hyperthermia.

Many factors in the environment affect the general pattern of the activities of *S. mitranus*. such as ground temperature, air temperature, and rain and cloud cover. Skink morphology seems to be well adapted to survival in its sandy desert habitat. The flattened body, the wedge-shaped head, the toe-fringes, and the enlarged scale covering the ear are all adaptative features to life in the sandy environment. The toe fringes aid in fast locomotion over the sand and the smooth body scales in sand swimming [26]. The skink was observed in the present study to utilize areas of hard and firm sand for fast running while chasing its prey.

The skinks spend most of their activity on the eastern sides of the sand dunes that face the rising sun and are 2-4°C warmer than the opposite face. They seem to utilize the prevailing conditions there to gain radiant heat, a known rapid mode of heating [27] in order to reach the eccritic body temperature optimal for normal activity. When the sand temperature exceeds 38°C, the skinks take refuge under plant cover or its shade, or dive into the sand to a depth of 5-10 cm to reach the cooler layers. Similar sequences of activity have also been described by Arnold [9].

The gradual rise in body temperature experienced by the skinks in their habitat would ultimately lead to hyperthermia, a situation which they are fully capable of dealing with. They again make use of all the existing factors and parameters in their environment to regulate their body temperature both on a daily, as well as a seasonal basis. In the present study the lizards were active throughout the year except during January when the temperature dropped to a mean of 13.1°C in the study area. However, the animals completely disappeared from the surface of the sand when the temperature dropped below 20°C. Hence, it appears that *S. mitranus* does have a range of temperatures within which it operates and extremes that it strictly avoids.

In summer the skink's morning period of activity seems to be limited by an optimum activity temperature, as they disappear in the sand towards midday and their afternoon session would only start when the temperature drops to tolerable levels after 1700 hours till sunset. In winter and early spring, optimum activity temperature seems to occur when air temperature is around 24-27°C and soil temperature is about 29-33°C. This is in accordance with the suggestions of Al-Johany [11] and George [12] that the thermal parameter is of utmost importance for diurnal lizards. However, the sand in which such lizards take refuge to avoid high temperature usually heats and cools fast, a situation that presents a difficult thermal habitat for such small diurnal desert lizards [12]. Nevertheless, the loose sand does provide an ideal condition for behavioral thermoregulation due to the possibility of movement in three dimensions and the existence of sharp temperature gradients [24]. Hence, burrowing into the sand can provide an excellent compensation for the narrow thermal niches, as the deeper layers can provide more stable and comfortable temperature and humidity levels almost all year round, though the animal's activity can be very much restricted by having to use these [12; 28].

As in most desert reptiles, the activity pattern of *S. mitranus* was observed to be bimodal in summer and unimodal in winter and early spring. Similar observations have been cited in other reports [see 11;12;17;20;24;29;30, pp.196-356; 31; 32; 33]. Moreover, as reported by Heatwole [17] for other heliothermic reptiles, the level of activity of *S. mitranus* observed in this study was higher in summer than in winter and spring, with the corresponding eccritic body temperature higher in summer than in winter.

In accordance with the observations that lizards thermoregulate by seeking refuge in plant cover and its shade when substrate temperature exceeds their own body temperature [9], the correlation between body temperature and ground temperature recorded during both summer and winter for *S. mitranus* in the present study was highly significant, and so was the correlation between body temperature and air temperature, with the summer always higher than the winter.

Seasonal differences in the mean body temperature of many reptiles including *S. mitranus* have been reported [9;11;34], a behavior reflecting some degree of adaptation of reptiles to deserts in terms of thermoregulation [35]. The observations on *S. mitranus* match those reported on other reptiles by Spellerberg [36], Regal [37] and Al-Johany [11], that the eccritic body temperature matches the selected body temperature in winter and spring.

The sand fish, *S. mitranus* showed no significant difference in its SBT between day and night phase (day $\overline{X}$=34.4°C and night $\overline{X}$=35°C). However, *S. mitranus* was observed to move at night towards the warm end of the thermal gradient and to dive into the sand. The SBT during day time of *S. mitranus* is similar to that obtained for *A. schmidti* and *A. boskianus* [11] and *Chalcides ocellatus* [38].

Reptiles, in general, and lizards in particular thermoregulate behaviorally in comparison to the homeotherms that basically thermoregulate physiologically. Behavioral thermoregulation in reptiles consists, of various postures (orientation towards the sun), including alternating of the exposed area of skin to the sun, and shuttling movement between sunlight and shaded areas. The observations of Cloudsley-Thompson [16,pp.39-59] and of Al-Johany [11] have determined that the body heat was behaviorally regulated by basking and avoiding high levels of isolation, a situation that showed efficiency and economy in energy terms compared to the costly physiological thermoregulation. Hence, all methods of posturing heliothermy, shuttling heliothermy and thigmothermy are extremely advantageous to reptilian thermoregulation. All these methods of behavioral thermoregulation were quite evident in the present study of *S. mitranus*.

Selection of an appropriate basking site is important, as had been observed in the case of *S. mitranus*, choosing eastern sides in the sand dunes of the study area. Also in the afternoon period, *S. mitranus* was seen foraging in slipfaces between the sand dunes. In general, when a reptile emerges after the initial basking, its body temperature would normally be between the voluntary body temperature or preferred temperature limits during all the activity period.

The present results on the CTMax of *S. mitranus* are similar to those reported for other species of lizards in central Arabia [9]. It is well known that reptiles from warm climate have a higher CTMax than species from cooler climate [39]. The CTMax value ($\overline{X}$=47°C) of the diurnal *S. mitranus* is higher than that of nocturnal lizard species, such as *Stenodactylus doriae* ($\overline{X}$=40.5°C) and *Bunopus tuberculatus* ($\overline{X}$=41 °C) [9]. This is in line with the study of Bradshaw [40] who indicated that CTMax of diurnal surface active lizards is higher than that of nocturnal and fossorial forms. Spellerberg [39] indicated that only two genera of skinks are known to pant (*Tiliqua* and *Menetia*), however, *S. mitranus* when subjected to higher temperatures are observed to pant, which suggests that this response is primarily of significance in thermoregulation.

The CTMin ($\overline{X}$=13°C) of *S. mitranus* was observed to be higher than that of *A. schmidti* ($\overline{X}$=7°C) and *A. boskianus* ($\overline{X}$=8°C) reported by Al-Johany [11]. This could be explained partly by the fact that *A. schmidti* and *A. boskianus* are active all year round. These lizards will emerge and bask in the sunlight during winter days and they become active about midday [11]. Therefore, low CTMin values would be advantageous to these species to survive cold temperatures during winter, while *S. mitranus* disappear during cold days of winter (January). The CTMax and CTMin of *S. mitranus* reflect the ability of these lizards to tolerate the drastic changes in the desert environment.

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البيئة الحرارية والنشاط لسحلية سمكة الرمل *Scincus mitranus* (عائلة السقنقورات) في وسط الجزيرة العربية

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ملخص البحث. تمت دراسة البيئة الحرارية والنشاط للسقنقور *Scincus mitranus* خلال فصلي الشتاء والصيف. وكذلك تمت دراسة وتحليل وقت ظهور الحيوانات وسلوك التشمس والنشاط الفصلي. وقد وجد أن هذه السحالي نشطة طوال العام عدا الأيام الشديدة البرودة خلال فصل الشتاء، ولكن نشاطها ينحصر في فترة واحدة خلال منتصف النهار؛ بينما يكون على فترتين، صباحية ومسائية خلال فصل الصيف، وقد تطرقت الدراسة أيضا إلى تحديد درجة الحرارة المفضلة ودرجة الحرارة الحرجة الدنيا والعليا في المختبر.