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A radiotelemetric study of the body temperature of *Varanus griseus* (Sauria: Varanidae) in Zaranik Protected Area, North Sinai, Egypt

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ABSTRACT
A radiotelemetric study of body temperature (T_b) of the desert monitor, *Varanus griseus* was carried out at Zaranik Protected Area in north Sinai from July 1997 to June 1998. The highest mean T_b of active lizards was recorded in summer. *V. griseus* showed unimodal activity in body temperature with peaks in May and June. The overall mean diel T_b from 0700 -2000 h was 32.6° C, higher at the midday hours (1100-1600 h). Emergence began 2- 4 h after sunrise, earlier during summer. During emergence, body temperature reached a maximum of 35.5°C. T_b of basking lizards ranged from 34.5-41.5°C, while moving individuals varied from 33.7-41.9°C. Males showed considerably higher mean body temperatures than females. Monitors introduced to the study site showed higher mean T_b than residents. Monitors moved into hibernation in October and November, and emerged in March and April. The body temperature for hibernating lizards ranged from 15-30.5°C .

KEYWORDS: radiotelemetry, home range, activity, *Varanus griseus*, Sinai, Egypt

INTRODUCTION

Radiotelemetry has provided researchers with a valuable method for studying aspects of animal ecology. Measuring body temperature from a distance, without disturbing the animal, is one of the useful applications of radiotelemetry (Christian & Weavers 1996; Thompson *et al.* 1999). The desert monitor, *Varanus griseus*, is a widespread in arid and semi-arid zones from northwestern Africa to northwestern India (Mertens 1942); it feeds mainly on rodents, bird eggs, birds, lizards, snakes, and tortoises, in addition to invertebrates (Stanner & Mendelssohn 1986; Tsellarius *et al.* 1997). In Egypt, it is found in sandy areas throughout the eastern and western deserts and in northern Sinai (Saleh 1997).

Thermoregulation of varanid lizards have been widely studied (Stebbins & Barwick 1968; King 1980; King *et al.* 1989; Wikramanayake & Dryden 1993; Traeholt 1995, Christian & Weavers 1994 &1996; Thompson *et al.* 1999) using radiotelemetry. However, *V. griseus* has received little attention, especially when using this technique (see Sokolov *et al.* 1975; Francaz *et al.* 1976; Francaz & Vernet 1978; Vernet *et al.* 1988b). Previous studies reported seasonal and diel variations in the body temperature of varanids. They attributed these changes to environmental conditions (King 1980), or to solar radiation (Christian & Weavers 1996). Sokolov *et al.* (1975) reported that the mean T_b of active *V. griseus* in the midday was 33.6° C in Turkmenistan. Vernet (1977) and Vernet *et al.* (1988b) concluded that the ecological optimum temperature for *V. griseus* in Algeria ranged from 35-38°C, and *V. griseus* becomes inactive at less than 20°C, relating this to the behavioural response to ambient temperature or the effect of food present. Auffenberg (1979) suggested that T_b of males was higher than in females of *V. bengalensis* since the male spent nearly twice as much time out of the burrow than females of both size classes. In Egypt, some ecophysiological data are available for

V. griseus, especially in relation to its hibernation (Khalil & Abdel-Messeih 1959a,b; Abdel-Raheem 1965; Haggag *et al.* 1966a,b; Abdel-Raheem & El Mosallamy 1979; Haggag *et al.* 1979a,b)

The aims of this work were: to investigate diel and seasonal variation in body temperature of the desert monitor; to determine differences in body temperature, if any, between individuals captured in the protected area (residents), and those captured from other area and introduced to the protected area (introduced); and to determine sexual differences in body temperature, if any, between and within both resident and introduced individuals. Thermoregulatory behaviour was also considered. It was also interesting to compare the body temperature of *V. griseus* in the Sinai desert to that of the same species in the East (Sokolov *et al.* 1975), and in the West (Vernet *et al.* 1988b). Since radiotelemetry is used for the first time in Egypt, this would pave the way for further ecological studies in the wild.

MATERIALS AND METHODS

The study was conducted at Fluseyyat Island of the Zaranik Protected Area in northern Sinai (31° 07' 02" N, 33° 25' 52" E). Fluseyyat Island is relatively small (12000 m^2), and is seasonally isolated from the mainland (Fig. 1). The vegetation on the island is dominated by *Panicum turgidum, Artemisia monosperma* and *Retama raetam.*

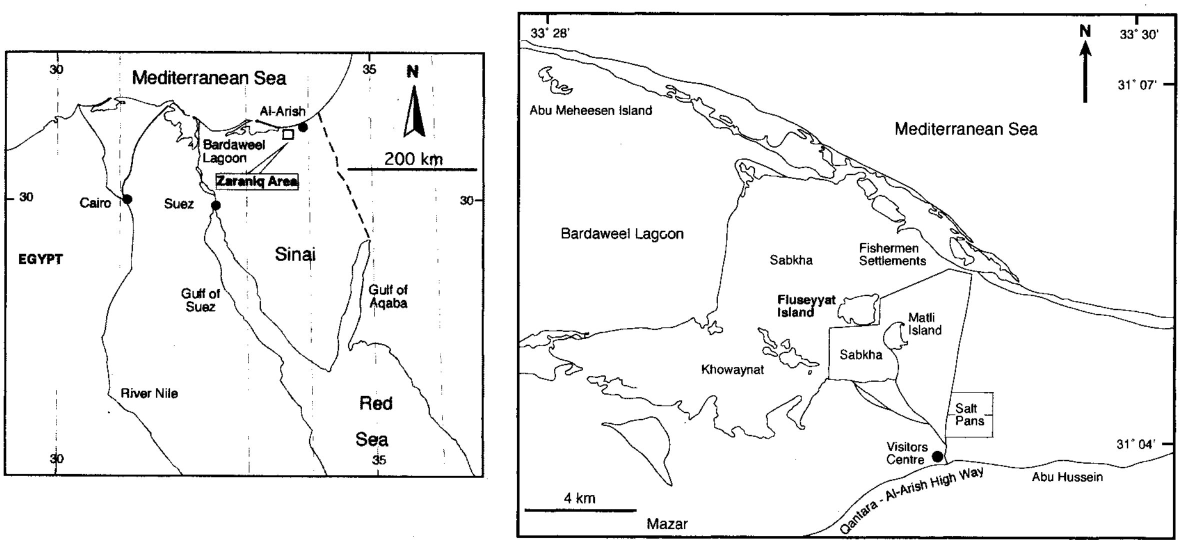

Fig. 1: Map of the Zaranik Protectored Area showing the study site.

Five healthy, medium-sized monitors of *Varanus griseus* (Fig. 2) were captured by following their tracks and digging them out of burrows just before sundown between 12 and 24 July 1997. Sex was determined by everting the hemipenes. One male (#1), and one female (#2), were captured from Fluseyyat Island. Two males (#3 and #4), and a female (#5) were captured from similar sand dunes, 3-5 km away and introduced to the island. Lizards were placed in cloth bags and cooled in a refrigerator at 3°C for 3- 4 hours prior to transmitter insertion (Table 1).

SI-2T temperature-sensitive transmitters (frequency 151-152 kHz, life span 14 months @ 20°C, mass 8.5 g, less than 5% of body mass: Holohil System, Ltd., Ontario, Canada) were surgically inserted subcutaneously and their whip antennas externally attached to the tail (Ibrahim 1999). A TRX-1000 receiver (Wildlife

Materials, Inc., Carbondale, Illinois, U.S.A.), and a Folding 3- Element Yagi Directional Antenna (Wildlife Materials, Incorporated, Carbondale, Illinois, U.S.A.) were used to locate the monitors.

Fig. 2: *Varanus griseus* in the study site

Table 1: Sex, mass, snout-to-vent-length, number of observations and maximum body temperature for *Varamus griseus*

Monitors	1	2	3	4	5
Body mass (g)	450	440	455	450	295
Snout-to-vent length (SVL) (mm)	36	34.5	34	33.5	30.2
Tail length (TL) (mm)	42	44.8	43.2	19 (cut)	39.7
Sex	female	Male	Female	Male	Male
Total number of days monitored	50	50	48	19	22
Total number of temperature observed	114	110	96	29	41
Mean T_b (standard deviation)	29.5± 4.4	33.5 ± 4.6	32.8 ± 4.8	31.8 ± 3.0	30.8± 6.0
Maximum T_b recorded	41.4°C	41.9°C	41.5°C	37.7°C	41.5°C

V. griseus were released after two days of capture at the same point on Fluseyyat Island. Tracking of lizards began two hours after release. In the first few days, lizards were located 5-7 times a day, and up to 14 days a month. Body temperature (T_b) was recorded while they were basking, moving during activity period, and occasionally in burrows during hibernation. Ambient temperatures were taken at a height of approximately 170-190cm above the ground using a digital Hygro-thermometer (Extech Instruments 445900) in an area shaded from the sun. Meteorological data were also obtained from Al-Arish Metreological station.

Temperature-sensitive transmitters produce a sound pulse, and the period between pulses decreases with increased T_b. To measure the interval between two beeps, a count of eleven pulses was taken at the location site, and the time between them measured to the nearest 0.01 second (using a stopwatch). The body temperature was then estimated from a standard graph provided by Holohil Systems. For statistical analysis, a paired t-test and one-way Anova were used; mean values are reported $\pm$ one standard deviation; all times are in local time (GMT +2 hrs).

To determine the time-range of emergence of lizards, fixes were taken in the early morning at the interval of one hour before emergence. In all fixes following emergence, animal tracks around the burrows were covered up. In order to locate the position of the animal in the burrow, the Yagi antenna was orentated in many directions around the burrow until the strongest signal was heard. Hence, the distance that the animal moved away from the burrow hole could be determined. At the end of the study, the transmitters were removed using a similar method. The surgical process and carrying of transmitters seemed to have little effect on lizard behaviour, since movements or activity patterns of *V. griseus* during the first seven days after release did not vary from those over the subsequent seven days. Later, a female with a transmitter inserted subcutaneously appeared to have laid eggs and was observed going back and forth to its nest.

RESULTS

Three hundred and ninety T_b observations were taken for *V. griseus* between 0700 and 2000h over a period of ten months (see Fig. 3). The T_b varied from 15 to 41.9°C (mean 31.7°C ± 1.6). The mean maximum T_b for all five *V. griseus* was 40.8 °C (± 1.7, n = 5) (Table1). The male monitor #4 was found dead in March for unknown reasons, and male #1 disappeared in May probably because of transmitter failure.

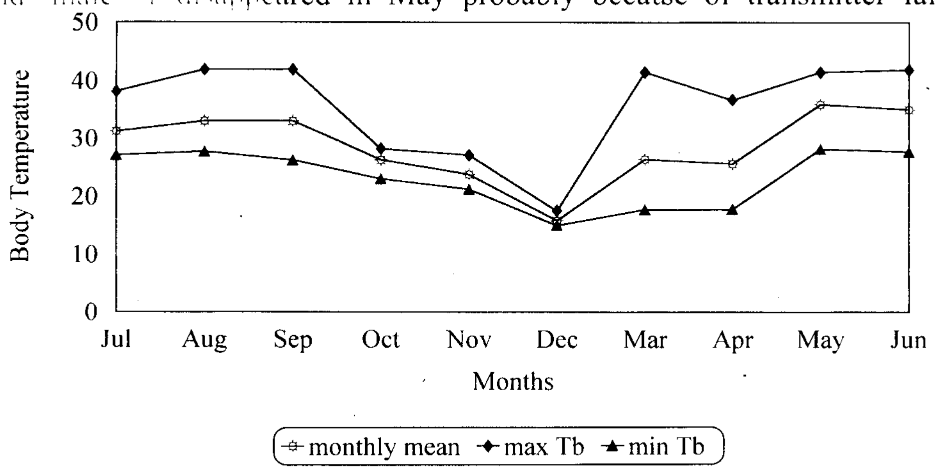

Fig. 3: Monthly mean, maximum and minimum body temperature for *Varanus griseus* (July 1997 to June 1998).

Diel and seasonal and variations in body temperature: The mean diel body temperature of active lizards fluctuated considerably throughout the year (Anova, $F_{12,346}$ = 3.4, p< 0.001) (Fig. 4). The overall field-active mean T_b from 0700 -2000 h was 32.6 °C ± 4.1 (n = 357). The mean T_b of active lizards recorded in the midday from 1100-1600 h was 33.1 °C ± 6.1 in spring, 33.4 °C ± 5.8 in summer, and 34.5 °C ± 3.7 in autumn.

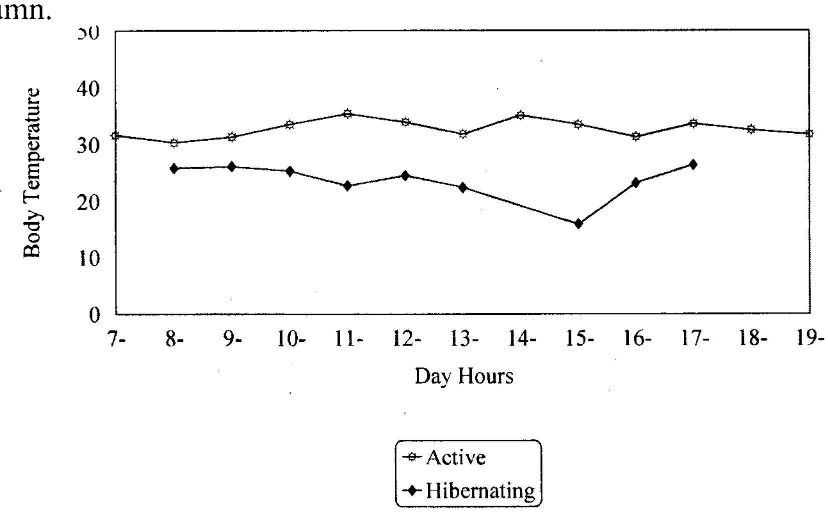

Fig. 4: Mean diel body temperature for active and hibernating lizards

The mean diel body temperature varied seasonally, overlapping among seasons. In spring, T_b fluctuated considerably with highest peak during 1400-1500 h. In summer, there was a little difference in mean T_b over most daylight hours. In autumn, there may have been bimodal activity with peaks from 1000-1100 h and 1400 - 1500 h (Fig. 5).

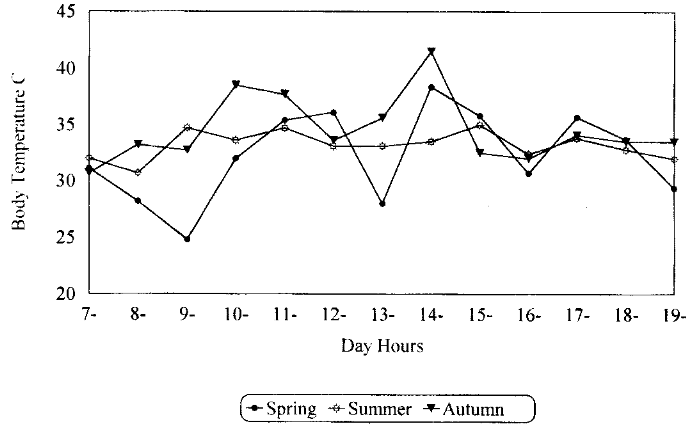

Fig. 5: Mean diel body temperature for *Varanus griseus* in different seasons

The annual activity of *Varanus griseus* is limited to seven months since they hibernate from October to November, emerging in March or April. Seasonal and monthly changes in body temperature of *V. griseus* were evident. Seasonally, the highest mean T_b of active lizards was recorded in summer (32.7 °C ± 3.2), followed by autumn (30.8 °C ± 4.7), and spring (30.7 °C ± 7.2), and these were significantly different ($F_{2,318}$ = 6.7, $p < 0.01$). The mean body temperature recorded in winter (December) while the monitors were hibernating was 15.8 °C ± 1.2.

By month, *V. griseus* showed unimodal changes in body temperature with a peak in May and June when the monitors were more active than in other months (Fig. 3). There was a highly significant difference in the body temperatures of individuals among months (Anova, $F_{6,351}$ = 34.3, $p<0.001$).

Body temperature at emergence and retreat: The time at which *V. griseus* emerged from their burrows in the morning was recorded only on a few occasions since these lizards were very alert and the study area was sparsely vegetated, enabling the varanids to see researchers some distance away. However, extensive fixing and tracking of animals before and after emergence and checking their tracks around burrows, showed that the time of emergence varied considerably within and between individuals. Emergence normally began 2-4 h after sunrise (from 0755 to 0930 h), and took up to 3 hours tending to be earlier during summer, especially in June. On two of ten occasions, lizards appeared 2 hours after sunrise. The body temperature of animals measured before emergence (from 0655 h to 0930 h), ranged from 27.7 to 34.5 °C (31.9 ± 2.1 °C, n = 24). During emergence, body temperatures reached 35.5 °C and 34.5 °C for #3 and #5 respectively in June.

Occasionally, one of the monitors would emerge in the afternoon, but I have no data on the precise times. Monitors also did not emerge from burrows at all for several days, even in summer. For example, female #2 moved only in the afternoon from 1500 to 1600 h on 29 May 1998. In August, she did not emerge from its burrow for 16 successive days.

The time at which lizards retreat to their burrows also varied considerably between and within individuals. However, the exact time of retreat into the burrows was impossible to determine, since the lizards were often found basking near their burrows in the late afternoon and their retreat may have a result of having been disturbed by the observer. Thus the exact T_b prior to retreating could not be measured. Lizards seemed to be active until about 35-40 minutes before the sunset. Some individuals retreated to their burrows more than 150 minutes before sunset. The maximum T_b recorded for a monitor in its burrow was 38.5 °C.

Body temperature of basking and movement: Although *V. griseus* is a very wary animal, it was occasionally possible to watch the animal through binoculars without disturbing it. On the 17 occasions, when they were watched while basking, T_b ranged from 34.5 - 41.5 °C (37.8 °C ± 1.5). In the morning hours, body temperature varied from 34.5 to 41.5 °C (37.8 °C ± 1.7 , n = 11), while in the afternoon hours ranged from 35.5 to 38.5 °C (37.8 °C ± 1.1, n = 6). The maximum difference between body temperature and air temperature while lizards were basking reached 20.5 °C. Body temperatures were also recorded sometimes while lizards were moving or running on the ground, varying from 33.7 - 41.9 °C (38.1 °C ± 2.7, n = 14). The maximum difference between body temperature and air temperature while lizards were moving or running was 22.4 °C.

Intersexual differences in body temperature: Males showed considerably higher mean body temperatures than females during activity seasons (t-test, t = 3.43, df = 318, $p<0.001$). Within sexes, there were significant differences among individual males (Anova, $F_{2,154}$ = 6.29, $p<0.01$), and females (Anova, $F_{1,163}$ = 24.23, $p<0.001$). The introduced monitors also showed higher mean T_b than the resident monitors (t-test, t = 5.72 df = 174, $p<0.001$). The introduced male #3 showed a greater mean T_b than the resident male #1 (t-test, t = 2.27, df = 39, $p<0.05$), and the introduced female #5 showed higher T_b than the resident female #2 during the highest activity months, May and June (t-test, t = 2.44 , df = 53, $p<0.01$).

Body temperature during hibernation: The monitors #1, #2, and #5 moved into hibernation in October and emerged in March, while #3 commenced hibernation in November and reappeared in April. On 22 November, the female #5 moved about three metres underground during hibernation at a T_b of 22.5 °C. Precise orientation of the Yagi antenna around burrow could give an accurate estimate of the distance that the lizard moved underground. The male #4 commenced hibernation in October, but was found dead in March. The body temperature for hibernating lizards (October-April) ranged from 15-30.5 °C (25.2 °C ± 3.9, n = 49). Body temperatures were neither measured during January nor February.

DISCUSSION

Diel and seasonal variations in body temperature: *Varanus griseus* generally began increasing their body temperature when they were first recorded in the morning (from about 0800 h) probably as a result of conductive heat gain. A more rapid increase was generally evident after 0930 h, presumably due to heat gained by radiation when basking in front of burrows. The maximum mean T_b was measured between 1100-1200 h; this may correspond to the end of the initial basking period often obvious in varanids (King 1980; King *et al.* 1989; Green *et al.* 1991).

The rise of the T_b of active lizards in the late afternoon from 1700 to 1800 h may be attributed to afternoon basking. However, a slight difference in T_b was noticed within afternoon hours. The rise occurred when the ambient temperature was declining and may have been the result of late afternoon basking. This is consistent with the results of Stebbins & Barwick (1968) who suggested that in late afternoon body temperature of the lace monitor, *V. varius* rose 1-2 °C above the general level encountered during the day.

The body temperatures of *V. griseus* were higher in the midday, but lower during early morning and evening. Similar findings are reported by Wikramanayake & Dryden (1993) for *Varanus bengalensis.* The mean T_b of active *V. griseus* from 1100 to 1600 h (33.6 °C) are lower than the middle of the range of 32.1 °C- 38.4 °C determined by radiotelemetry for *V. griseus* given by Sokolov *et al.* (1975) in Turkmenistan. However, the mean T_b of *V. griseus* in the midday in summer (33.4 °C) is comparable to tropical Australian *Varanus* (Christian & Weaver 1996), equaling that of *Varanus mertensi* in the dry season (June to July), higher than that of *V. gouldii* (28.2 °C), and less than that of *V. panoptes* (36.2 °C). Thus my results seem to be consistent with other studies of the genus.

The mean body temperatures (T_b) for *V. griseus* when active varied between seasons. The mean T_b of *V. griseus* was higher in summer more than in autumn and spring. The seasonal changes of body temperature may be related to the prevailing weather in Sinai deserts. Vernet (1977), and Vernet *et al.*(1988 b) reported similar seasonal changes, but their values were higher than those recorded for *V. griseus* in this study. They suggested that the ecological optimum temperature for *V. griseus* ranged from 35-38 °C. Christian & Weavers (1996) report significant differences between seasons in T_b among the varanid species they studied in tropical Australia, attributing the difference to solar radiation.

The maximum mean body temperatures for active lizards were recorded in May and June (35.9 °C and 35 °C respectively). These are lower than those reported for the same species in summer by Vernet *et al.* (1988 b). There were probably factors other than air temperature, such as food and habitat type that might play a key role in influencing body temperature for *V. griseus* in Sinai. Varanid lizards possess a considerable degree of physiological control over their body temperature (Bartholomew & Tucker 1964; Grenot 1968, Bennet 1971, 1972, 1973).

Body temperature of emergence and retreat The morning emergence of lizards has been attributed to several factors including endogenous rhythms (Heath 1962), and temperature-dependent emergence (Bradshaw and Main 1968). The emergence of *V. griseus* over a period of three hours, and its tendency to emerge earlier in summer than in spring and autumn are similar to the behavior of *V. gouldii* on Kangaroo island, south Australia (King 1980). However, the body temperature of *V. griseus* before emerging is higher than recorded for *V. gouldii.* This is apparently a function of the difference in climatic factors. As here, considerable individual variation in time of emergence has been found for elsewhere *V. griseus* in the wild (Sokolov *et al.* 1975; Vernet *et al.* 1988 a). King (1980) related the considerable variation in time of emergence of individual animals to the environmental conditions rather than a biological rhythm.

Body temperature of basking and movement: Results revealed that *Varanus griseus* could increase its body temperature quickly, especially in the morning hours. The maximum body temperature for basking lizards did not normally exceed 38.5 °C, except for the male monitor #1 which increased its T_b from 22.5 to 41.5 °C at 1025 h in March. This elevation in temperature may be attributed to the small size of this male compared to other males. Auffenberg (1979) suggested that the basking time was generally shorter in larger than smaller males of *Varanus bengalensis.* The maximum T_b recorded during morning basking was higher than the maximum T_b recorded in the afternoon hours. Thompson *et al.* (1999) related the maximal increase of body temperature of *V. tristis* during midday to basking during morning hours. Also, the relatively high body temperature of *V. griseus* just before retreat was evident in this study, probably a result of afternoon basking. Similar findings were reported by Stebbins & Barwick (1968).

Considerable difference between body temperature and air temperature while *V. griseus* were basking or moving is evident in this study. This difference might be a reflection of solar radiation and the soil temperature that reached its maximum (51.8 °C) in July. Similar findings were reported for congenerics elsewhere (Stebbins & Barwick 1968; King 1980). The deficiency of data on the body temperature of basking lizards precludes a seasonal analysis to find out the difference in body temperature of basking lizards among different seasons.

Intersexual differences in body temperature: Males were usually more active than females of both residents and introduced individuals, attaining higher home range size, and higher overall mean distance per day and per move than the females (Adel Ibrahim, unpublished data). This may reflect their higher mean body temperature. Auffenberg (1979) found that the male *V. bengalensis* spend nearly twice as much time out of the burrow than females of both size classes. In addition, the introduced lizards (#3 and #5) maintained a higher frequency of movement than the resident individuals (#1 and #2) (Adel Ibrahim, unpublished data), and were found to have a higher mean body temperature.

Body temperature during hibernation: The hibernation of *V. griseus* in October and November in Egypt has been previously documented (Haggag *et al.* 1966 a). In this study, *Varanus griseus* hibernated with higher body temperatures (15-30.5 °C) when compared with the same species in other areas (Vernet *et al.* 1988 b). The mean daily air temperatures recorded in October and November were 22.4 °C and 21.2 °C respectively. Vernet *et al.* (1988b) suggested that *V. griseus* in Algeria becomes inactive at less than 20 °C and its hibernation temperature is generally between 16-18 °C. This difference in temperature reflects the difference in climate between the two areas, especially in winter. It might also be due to the behavioural response to ambient temperature T_a, or the influence of prey availability.

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الملخص العربي

دراسة راديوتليمترية على درجة حرارة جسم الورل الصحراوي *فارانس جريسياس*" فى محمية الزرانيق، شمال سيناء، مصر.

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أجريت دراسة راديوتليمترية على درجة حرارة الجسم للورل الصحراوي "*فارانس جريسياس*" فى محمية الزرانيق فى شمال سيناء فى الفترة ما بين يوليو ١٩٩٧ إلى يونيو ١٩٩٨. سجلت أعلى درجة حرارة فى فصل الصيف (٣٢,٧°م ± ٣,٢) ، تلتها فى فصل الخريف (٣٠,٨° م± ٤,٧) ثم فى الربيع حيث بلغت (٣٠,٧ °م ± ٧,٢) . ولقد أظهر الورل نشاطاً غير منتظم فى درجة الحرارة وقد بلغت أعلي قيمة للحرارة فى شهري مايو ويونيو. كان المتوسط الكلي لدرجة الحرارة من السابعة صباحاً إلى الثامنة مساءاً (٣٢,٦ °م ± ٤,١) بينما فى منتصف اليوم (١١ صباحاً إلى الرابعة مساءاً) بلغت (٣٣.١°م ± ٦,١) فى فصل الربيع ، (٣٣,٤°م ± ٥,٨) فى فصل الصيف ، وأخيراً (٣٤,٥ °م ± ٣,٧) فى فصل الخريف.

بدأ خروج الحيوان من الجحر بعد شروق الشمس بساعتين إلى أربع ساعات ، ولقد كان هذا الخروج مبكراً إلى حد ما فى فصل الصيف . وأثناء الخروج ، وصلت درجة حرارة جسم الحيوان إلى ٣٥,٥°م و ٣٤,٥°م لكل من الورلين رقم ٣ و ٥ على التوالي فى شهر يونيو. أما عن درجة حرارة التشمس فقد تراوحت من ٣٤,٥ °م إلى ٤١,٥°م (٣٧,٨ °م ± ١,٥) ، بينما تراوحت للأفراد المتحركة النشطة ما بين ٣٣,٧°م إلى ٤١,٩°م (٣٨,١°م ± ٢,٧ عدد الأفراد = ١٤). كان متوسط درجة حرارة الذكور أعلي بكثير من الإناث فى مواسم النشاط . وكذلك فإن الأفراد المتنقلة كانت درجة حرارتها أعلى من درجة حرارة الأفراد المقيمة. وانتقلت الحيوانات إلى البيات الشتوي فى شهري أكتوبر ونوفمبر وخرجت منه فى مارس وأبريل ، وأثناء البيات الشتوي تراوحت درجة حرارتها ما بين ١٥°م و ٣٠,٥°م (٢٥,٢ °م ± ٣,٩ عدد الأفراد = ٤٩).