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ACTIVITY OF A NOCTURNAL LIZARD *(Stenodactylus doriae)* DURING A LUNAR ECLIPSE AT HAZEVA (ISRAEL)

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ABSTRACT:

The nocturnal, terrestrial, *S. doriae* is common on sands at Hazeva, Wadi 'Arava, Israel. Asking whether and how its activity changed during the full lunar eclipse of 17/X/1986, we recorded gecko activity by two methods, dividing each night into two-hour periods. Bouskila et al. (15-19/X) counted tracks on a cleared 30 m sand strip: tracks were significantly fewer in the two darkest hours (eclipse) than in other periods of the same night or the same periods of other nights. Y.L. Werner et al. (17-18/X) scouted with electric torches for geckos on the surface; these were at least as frequent during the eclipse as during other hours of 17/X and the same hours of 18/X. This species has been reported to be more active (as shown by tracks) in moonlit than in moonless nights. The observations seem compatible with other data that in lizards, emergence is circadian. But locomotor activity increases with actual moonlight.

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INTRODUCTION

Animals exhibit 24-h cycles of activity, commonly modulated by the annual cycle of seasons, the details of timing varying among species (Sollberger, 1965; Aschoff, 1969; Frankenberg, 1978). An additional, superimposed, cyclical modification sometimes occurs, coincident with the lunar month or moonlight. Lunar effects have initially been studied mainly in marine invertebrates (Sollberger, 1965; Brown, 1973). Alee et al. (1949) have stated that "periodicity induced or controlled by the moon... is of relatively little consequence to the terrestrial communities..."

But one may expect the lunar cycle, or at least moonlight, to have a considerable effect in desert ecosystems, because, on the one hand, many desert animals are nocturnal, and, on the other hand, in the open habitat much of the predation is visual, the animals being adapted to poor light (Walls, 1942). Indeed, in recent decades several studies indicate a generalization that the surface activity of nocturnal vertebrates tends to be affected by moonlight dichotomously: The activity of prey animals, e.g., rodents, is reduced but that of visual predators, e.g., nightjars and carnivores, is increased (Frankenberg and Werner, 1979; Butynski, 1984). For animals such as insectivorous lizards or small snakes the question arises, whether their costs-benefits balance (Rosenzweig, 1974) leads them to behave as prey or as predators. A second question arises, whether animals which appear to respond to moonlight possess an entrained (or even endogenous) lunar-cyclical variation of activity, or respond directly to the actual level of illumination (Enright, 1974).

In the diurno-nocturnal (Werner, 1969; =

nocturnal but not strictly nocturnal, Walls, 1942: 144) gecko *Ptyodactylus hasselguistii* kept in an isolated room with pseudonatural light and temperature cycles, the animals (males) were significantly more active (in an actograph) at the times of moonlight (Frankenberg and Werner, 1979). Such spontaneous cyclical activity does not prove, in these circumstances, that the animals are entrained to the lunar cycle (or have an endogenous cycle - Aschoff, 1960). The animals could be perceiving and responding to subtle moon-relation geophysical factors (Brown, 1960).

Since laboratory experiments, especially in actographs or small cages, have yielded controversial results (Marcellini, 1971; Lockard and Owings, 1974a), one may wish to separate the two factors, lunar illumination and lunar position, in the field. Other than expensive artificial illuminating or shading, this is achieved by two natural phenomena: a) Heavy clouding, with the drawbacks that it is grădual, accompanied by other meteorological deviations, and not sufficiently predictable to the investigator, and b) Lunar eclipse, with the advantages that it is decisive, meteorologically neutral and known (presumably not to the animals) a long time in advance.

We therefore endeavoured to utilize the full lunar eclipse of 17 October 1986 for observing the effects of this "unpredictable" period of complete darkness within the full-moon phase, on an abundant small nocturnal vertebrate, amenable to direct observation in the field.

MATERIAL AND METHODS:

Animal:

The above conditions are optimally met by *Stenodactylus (Ceramodactylus) doriae* (Blanford, 1874) (Reptilia: Sauria: Gekkonidae: Gekkoninae). This is a psammophilous ground-dweller in deserts of southwestern Asia (Arnold, 1980); its westernmost outpost is in the sand patches of the Arava Valley, Israel (Werner, 1987), where its populations appear to be uniquely dense (Bustard, pers. com. to YLW; Bouskila and Bonn, in MS). The usual ra (rostrum - anus size) of females is up to 70 mm; tail, 90 percra (percent ra - Werner, 1969); males are smaller (Arnold, 1980). The eyes are extremely large, 7.8 percra (Werner, 1969). In a laboratory investigation of the diel activity of 14 species and subspecies of geckos from Israel and elsewhere, this species was the most extremely nocturnal one (at least in summer) (Frankenberg, 1978). In the field its activity on the surface is nocturnal (Bouskila and Bonn, in MS); daytime is spent in burrows dug by itself in the sand (Bouskila, 1987).

Habitat:

The endogenous sand dunes and sand-fields near the Hazeva Field Study Center, in the northern Arava Valley within the extreme desert (30° 46'N - 30° 15'E, 135 m below sea level). Annual precipitation, very variable, averages 70 mm, usually delivered in 10 - 15 rainy days, in winter. Relative humidity averages 44% (23% at summer mid-days, up to 80% in winter); cloud cover is minimal. The hottest month is August: average daily maximum 38.4 °C, minumim, 24.3. The corresponding values for the coldest month, January, are 19.3 and 8.3 °C. Radiation ranges from 0.75 Kcal per cm^2 per day in June to 0.325 in January (Bouskila, 1984). Some microclimatic measurements have been published by Warburg (1964). The dominant plants are scattered *Acacia tortilis* trees, bushes of *Nitraria retusa* and *Traganum nudatum*, and grass clumbs of *Panicum turgidum*.

Procedures:

Two methods were employed: one team (headed by Bouskila) counted the distinctive tracks of the geckos where they crossed a cleared sand strip 300 m long (Bouskila and Bonn, in MS). Because of erroneous advance information that the two darkest hours would be 2050 - 2250 (17/X/86) (rather than 2020 - 2220 h), the strip was checked and cleared every two hours from 1650 h to 0050 h, and again at 0550. Exactly the same schedule was kept, as a control, during the two preceding nights (15 & 16/X). During the succeeding nights (18/X - 19 /X) the schedule could not be followed.

Another team (headed by Y.L. Werner) actively located and censused geckos on the surface, using electric torches, and tape-recording a continuous comment. A similar route was followed from 1740 to 2310 h on the night of the eclipse and next night as a control. The results were inspected in two-hour segments, both by the schedule of the first team and as based on the actual timing of the eclipse (darkest segment, 2020 - 2220 h). In both cases the record in some segment had to be corrected for time spent on examining snakes, etc.

RESULTS:

Environment:

On 17/X at Hazeva, the sun rose at 0600 h, set at 1720 h; the moon rose at 1710 h, and set at 0500 h (18/X). The eclipse proceeded so that by 2018 h only a 1/4 moon remained, by 2046 h it had disappeared, and by 2220 h a 1/4 moon had reapeared. There was an occasional light cloud cover which did not hide the moon, and little wind. On 18/X the moon rose at 1740 h, set at 0600 h (19/X). Cloud cover resembled the preceeding day but there was more wind. The course of surface temperature was very similar during both nights (within 1 °C): from 28.3 °C at 1730 h, through 25.2 °C at 2030 h to 23.9 °C at 2155 h; air temperature at 2-3 cm above ground was identical or higher by up to 1 °C.

Tracks:

On the night of the eclipse, out of a total of 53 gecko tracks that were observed during the 6 hours centered on the eclipse, only 9 tracks (17.0%) were observed during the central 2-h period of the eclipse itself. We compared this proportion to that on the two preceeding (control) nights. These closely resembled each other in the temporal distribution of tracks (P= 0.63 by a t-test for equality of proportions, using the arcsine transformation - Sokal and Rohlf, 1981), so the observations of both nights were pooled: 49 tracks, out of a total of 107 tracks (45.8%) occured during the 2-h periods corresponding to that of the eclipse. Hence gecko locomotor activity, as measured by gecko tracks, decreased very significantly during the lunar eclipse (P= 0.0001 by the same test).

Animal count:

Dividing the nights into two hour periods by either schedule, we have a 2-h control period before the eclipse period, but only a single control hour after. By the schedule used for the tracks, in the night of the eclipse out of 68 sightings of animals on the surface during the total 5 h (after correction for search effort), 29 were during the eclipse period. During the following (control) night, the percentage in this case was lower: out of 52 sightings (corrected as above), only 18 were during the 2-h period corresponding to the eclipse (34.6%). (By the schedule based on accurate eclipse times, the discrepancy increases, the respective values being 42.8% and 28.0%.) Hence presence on the surface was not depressed during the eclipse.

DISCUSSION:

The main results, that during the lunar eclipse the locomotor activity of *S. doriae* was depressed, leads to the conclusion that the nocturnal activity of this species (directly or indirectly) depends on moonlight. This conclusion is in agreement with another observation recently made on this species. Bouskila and Bonn (in MS) have counted tracks over a sandstrip to monitor the total activity of several nocturnal reptiles and mammals at Hazeva on 32 whole nights during june-october 1986. Comparing the numbers of *S. doriae* tracks on nights moonlit in their first half (full - moon quarter plus waxing-moon quarter of the month) to those on nights dark in the first half (new-moon quarter plus waning-moon quarter), they found that the activity on moonlit nights was twice that on dark nights. Hence *S. doriae* acts in this matter as a predator, like *Ptyodactylus h. guttatus* (Frankenberg and Werner, 1979). These observations may explain why Werner (1977), searching for *Palmatogecko* (an apparent, partial, convergent of *S. doriae*) in the Namib dunes, failed to find more during a lunar eclipse than on other nights. Furthermore, some doubts must be cast on the validity of earlier casual impressions, that in Israel the nocturnal activity of *Stenodatylus spp.* is depressed in full moonlight (Frankenberg and Werner, 1979). On the other hand, the effects of moonlight may vary seasonally (Lockard and Owings, 1974b; Rosenzweig, 1974).

The "predator's response" of *S. doriae* contrasts not only with the avoidance of moon-light shown by several rodents in North America (Blair, 1943; Lockard and Owings, 1974a; Clarke, 1983), but also with the behavior of gerbils in the Hazeva sands ecosystem: Bouskila and Bonn (in MS) have also shown, that gerbil activity during the full-moon quarter of the month was half that in any other quarter.

The counts of animals on the surface also merit consideration. The percentage of geckos counted during the 2-h period of the eclipse was not lower on the night of the eclipse than in the corresponding period of the following night, when gecko activity was presumably depressed by wind. Clearly, the eclipse only depressed the locomotor activity of geckos which actually were present on the surface.

Earlier studies have distinguished between emergence and activity: in diurnal, heliothermic, iguanids, emergence is dictated by an internal clock; thereafter locomotion depends on temperature (Heath, 1962; Evans, 1966). In several nocturnal geckos, too, emergence has been found to depend on an internal clock (Evans, 1967; Prince, 1970; McIvor, 1973) which at least in *Hemidactylus frenatus* is readily re-entrained (Frankenberg and Werner, 1981). Locomotion depends on temperature in some species (Bustard, 1967; 1968; Frankenber, 1979) but in some other species it appears to be restricted to the early hours of darkness irrespective of temperature (Bustard, 1970; McIvor, 1973). Now we see that locomotion may also depend on the level of illumination. Geckos, even those foraging at night, are visual hunters; they also have appropriately large eyes (Werner, 1969). Although *S. doriae* on the surface during the eclipse presumably had emerged before the eclipse, their relative inactivity again demonstrates the distinction between emergence and activity.

CONCLUSIONS:

1 - The locomotor activity of the nocturnal psammophilous gecko *Stenodactylus doriae* on the surface increases in full moonlight, decreases in darkness. This decrease occurs during a "random" full lunar eclipse, similarly to its regular occurrence in the nights of the dark phases of the moon.

2 - Hence the cyclical monthly suppression of activity during the dark quarter(s) of each month, too, may be a response to the level of illumination.

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LITERATURE CITED:

ALEE, W.C., A.E. EMERSON, O. PARK, T. PARK & K.P. SCHMIDT. 1949. Principles of animals ecology. *Saunders, Philadelphia & London* : 1 - 837.

ARNOLD, E.N. 1980. A review of the lizard genus *Stenodactylus* (Reptilia: Gekkonidae). *Fauna of Saudi Arabia* 2: 368 - 404.

ASCHOFF, J.1960. Exogenous and endogenous components of circadian rhythms. *Cold Spring Harbor Symp. Quant. Biol.* 25: 11 - 28.

----- 1969. Phasing of diurnal rhythms as a function of season and latitude. *Oecologia (Berl.)* 3: 125 - 165 (in German).

BLAIR, W.F. 1943. Activities of the Chihuahua deer mouse in relation to light intensity. *J. Wild. Manage.* 7: 92 - 97.

BOUSKILA, A. 1984. Habitat selection, in particular burrow location, in the dabb-lizard, *Uromastyx aegyptius*, near Hazeva. *M. Sc. Thesis in Environmental Biology. The Hebrew University of Jerusalem* : 1 - 161 + 5 pl. (In Hebrew; English Abstract 7 pp.).

----- 1987. The burrowing ecology of a desert gecko. *Abstracts, Joint Annual Meeting, Society for the Study of Amphibians and Reptiles, Herpetologists' League and Comité Herpetológico Nacional, Veracruz, México* : 52 - 53.

----- & J. BONN (in MS). Divergent effects of moonlight on the activity of desert vertebrates.

BROWN, F.A. Jr. 1960. Response to pervasive geophysical factors and the biological clock problem. *Cold Spring Harbor Symp. Quant. Biol.* 25: 57 - 71.

----- 1973. Biological rhythms. In C.L. Prosser (ed.), *Comparative animal physiology, Saunders, Philadelphia, London & Toronto*, 1: 429 - 456.

BUSTARD, H.R. 1967. Activity cycle and thermoregulation in the Australian gecko *Gehyra variegata. Copeia* 1967: 753 - 758.

----- 1968. Temperature dependent activity in the Australian gecko *Diplodactylus vittatus. Copeia* 1968: 606 - 612.

---- 1970. Activity cycle of the tropical house gecko, *Hemidactylus frenatus*. *Copeia* 1970: 173 - 176.

BUTYNSKI, T.M. 1984. Nocturnal ecology of the springhare, *Pedetes capensis*, in Botswana. *African J. Ecol.* 22: 7 - 22.

CLARKE, J.A. 1983. Moonlight's influence on predator/prey interactions between short-eared owls *(Asio flammeus)* and deermice *(Peromyscus maniculatus)*. *Behav. Ecol. Sociobiol.* 13: 205 - 209.

ENRIGHT, J.T. 1974. Relationships between circannual rhythms and endogenous lunar and tidal rhythms. In E.T. Pengelley (ed.), *Circannual clocks: annual biological rhythms. Academic Press, New York*: 249 - 251.

EVANS, K.J. 1966. Responses of the locomotor activity rhythms of lizards to simultaneous light and temperature cycles. *Comp. Biochem. Physiol.* 19: 91 - 103.

---- 1967. Observations on the daily emergence of *Coleonyx variegata* and *Uta stansburina*. *Herpetologica* 23: 217 - 222.

FRANKENBERG, E. 1978. Interspecific and seasonal variation in daily activity times in gekkonid lizards (Reptilia, Lacertilia). *J. Herpetol.* 12: 505 - 519.

---- 1979. Influence of light and temperature on daily activity patterns of three Israeli forms of *Ptyodactylus* (Reptilia: Gekkonidae). *J. Zool. London* 189: 21 - 30.

---- & Y.L. WERNER. 1979. Effect of lunar cycle on daily activity rhythm in a gekkonid lizard, *Ptyodactylus*. *Israeli J. Zool.* 28: 224 - 228.

----- & ---- 1981. Adaptability of the daily activity pattern to changes in longitude, in a colonizing lizard, *Hemidactylus frenatus*. *J. Herpetol.* 15: 373 - 376.

HEATH, J.E. 1962. Temperature-independent morning emergence in lizards of the genus *Phrynosoma*. *Science* 138: 891 - 892.

LOCKARD, R.B. & D.H. OWINGS. 1974 a. Moon-related surface activity of bannertail *(Dipodomys spectabilis)* and Fresno *(D. nitratoides)* kangaroo rats. *Anim. Behav.* 22: 262 - 273.

---- & ----- 1974 b. Seasonal variation in moonlight avoidance by bannertail kangaroo rats. *J. Mammalogy* 55: 189 - 193.

MARCELLINI, D.L. 1971. Activity pattern of the gecko *Hemidactylus frenatus*. *Copeia* 1971: 631 - 635.

McIVOR, I. 1973. Activity and daily breathing patterns of the gecko, *Hoplodactylus pacificus* Gray. *Mauri Ora* 1: 91 - 94.

PRINCE, G. 1970. Activity of some geckos, related to their nocturnality. *B. Sc. Honors Thesis, Univ. Western Australia*: 1 - 35.

ROSENZWEIG, M.L. 1974. On the optimal above-ground activity of bannertail kangaroo rats. *J. Mammalogy* 55: 193 - 199.

SOKAL, R.R. & F.J. RHOLF. 1981. Biometry (2nd ed.). *Freeman, San Francisco*: 1 - 368.

SOLLBERGER, A. 1965. Biological rhythm research. *Elsevier, Amsterdam, London & New York*: 1 - 461.

WALLS, G.L. 1942. The vertebrate eye and its adaptive radiation. *Bull. Cranbrook Inst. Sci.* 19: 1 - 785.

WARBURG, M.R. 1964. Observations on the microclimate in habitats of some desert vipers in the Nagev, Arava and Dead Sea region. *Vie et Milieu* 15: 1017 - 1042.

WERNER, Y.L. 1969. Eye size in geckos of various ecological types (Reptilia: Gekkonidae and Sphaerodactylidae). *Israel J. Zool.* 18: 291 - 316.

---- 1977. Ecological comments on some gekkonid lizards of the Namib Desert, South West Africa. *Madoqua* 10: 157 - 169.

----- 1987. Ecological Zoogeography of the Sahara-Arabian, Saharan and Arabian reptiles in the sand deserts of southern Israel. In F. Krupp, W. Schneider & R. Kinzelbach (eds.), *Proc. Symp. Fauna and Zoogeography of the Middle East, Mainz, 1985. Beihefte tum TAVO, Ludwig Reichter Verlag, Wiesbaden* A 28: 272 - 295.