Does the moon influence the predatory activity of mites?

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Abstract. Periodicity in predatory activity was observed in overwintered females of *Typhlodromus pyri* Scheuten (Acari: Phytoseiidae). Chronobiometrical analysis revealed that an approximately circabiseptan (about-14-day) rhythm is statistically significant, with a striking depression around the full moon.
Key words. Lunar cycle; mites; predatory activity.

The influence of the phase of the moon on insects, including species which are not nocturnal, and in which the effects cannot be explained by the influence of moonlight, has been reported by several authors[1–11]. However, no evidence was given that lunar periodicity also influences predatory activity. When we studied the overwintered females of the predatory mite *Typhlodromus pyri* Scheuten (Acari: Phytoseiidae) under constant laboratory conditions, we noted certain oscillations in consumption of prey. The regularity of these oscillations led us to test whether they could be the result of an influence of lunar periodicity on *T. pyri*.

Materials and methods

The laboratory cultures of *T. pyri* were started with overwintered females which had been collected in an apple orchard during the end of January. In 26 individually-reared females the daily consumption of prey, and fecundity were registered. The mites were kept at 18 °C, with 75% relative humidity and an 18L:6D light regimen until all had died. Diapausing females of *Tetranychus urticae* Koch (Acari: Tetranychidae) were used as prey to ensure that each individual had a standard nutritional value. As a surplus of fresh prey was always available to the predators and rearing units were so small that the predators had to spend no time searching for food, the number of prey consumed can be considered as the maximum predatory capacity of the females at a given time. Data were expressed in terms of an average daily consumption (C_t) and fecundity (F_t) per female. Moving averages (MA_t) of C_t and F_t respectively, used for the chronobiometrical analysis[13], were calculated for each time t, from three consecutive average daily values each. Halberg's cosinor analysis, modified by Bonferroni[13,14], was used to test for the presence of periodic components.

Results

Average daily consumption per female (C_t) plotted against time (t) of observation (fig. 1) shows an increasing trend up to the 65th day, followed by a marked decrease. The general shape of that curve is related to a similar baseline trend in fecundity. Overwintered females laid eggs singly, usually one egg every day, but they did not start and complete their oviposition period at the same time. The dynamics of predatory activity reflected the dynamics of oviposition, because the rate of food intake appeared to be positively correlated with the ovipositional rate in a remarkably linear pattern. This was shown in the present study ($r = 0.82$, $p < 0.001$) and in previous work[12]. However, there are much more striking oscillations of moving averages for the consumption of prey than for oviposition (fig. 1). We proposed the hypothesis that these predation oscillations could be related to the lunar cycle.

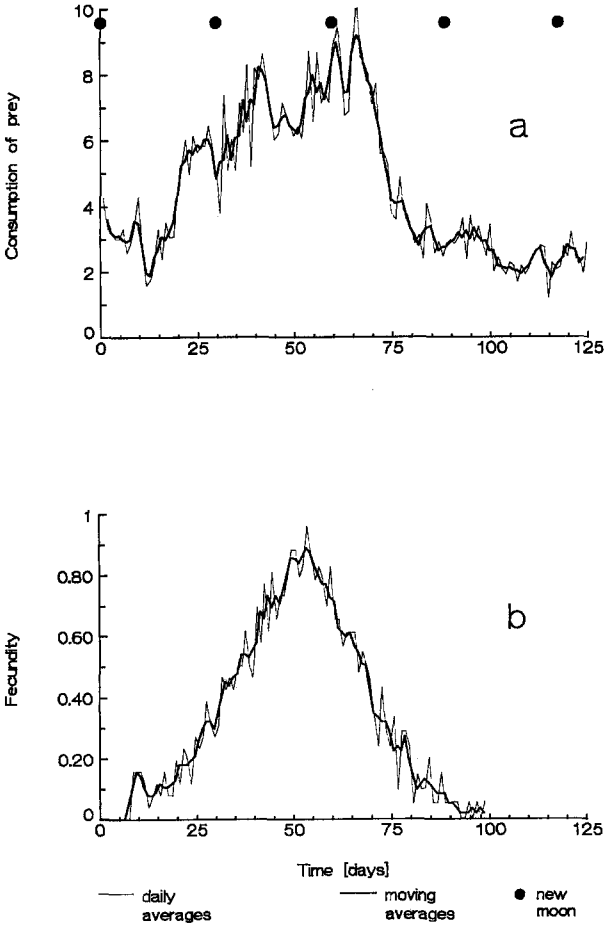

Figure 1. *a* Average daily consumption of *T. urticae* per one female of *T. pyri*. *b* Average daily fecundity of *T. pyri*.

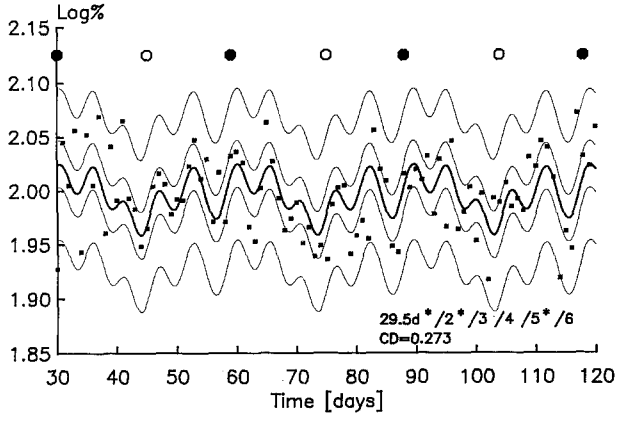

Figure 2. Predatory activity of females during 3 synodic lunar cycles expressed in *log*% of moving averages (see text) and fitted by regression with 6 periodic components (lines showing the narrower 95% confidence and wider 95% tolerance corridor, *significant at the level $\alpha = 0.05$, CD: coefficient of determination).

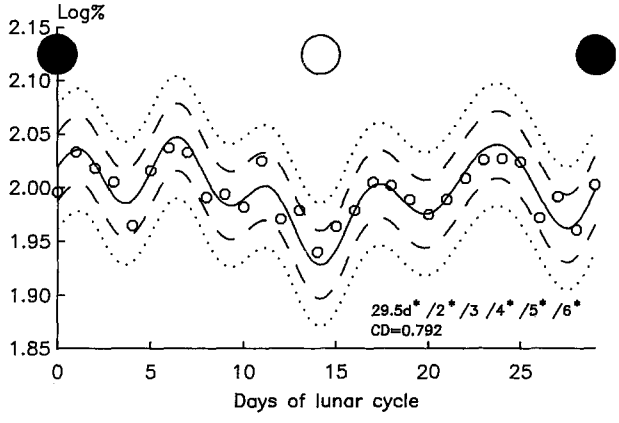

Figure 3. Predatory activity (*log*% of moving averages – dots) plotted against day of lunar cycle and approximated by regression (lines showing the narrower 95% confidence and wider 95% tolerance corridor, *significant at the level $\alpha = 0.05$, CD: coefficient of determination).

For the chronobiometrical analysis[13], moving averages (MA_t) of C_t were used (fig. 1). Each MA_t value was transformed to the logarithm of the percentage of the preceding MA_{t-1} value (*log*%, fig. 2) in order to suppress the effect of the baseline dynamic related to oviposition. Halberg's cosinor analysis, modified by Bonferroni[13,14], was applied to test the presence of 6 periodic components with period lengths of L (synodic lunar cycle), $L/2$, $L/3$, $L/4$, $L/5$ and $L/6$. The fitted chronogram, between the 30th and the 120th day of observation, for predatory activity expressed as *log*% of moving averages, revealed a depression at full moon. At the significance level $\alpha = 0.05$ the chronogram also showed $L/5$ ($p = 0.006$), L ($p = 0.021$) and $L/2$ ($p = 0.039$) components (fig. 2). The first and the last lunar cycles were omitted, due to the initial and terminal irregularities. However similar results were also obtained for all, non-reduced data. For each day of the synodic lunar cycle, 3 *log*% values (i.e. those from 3 lunar cycles for each day of L, where $t = 0$ is the day of the new moon) were averaged with weighting based on the value of the corresponding MA_t. The resulting plexogram also shows a striking depression around the full moon (fig. 3), and the $L/5$ ($p = 0.001$), $L/2$ ($p = 0.004$), L ($p = 0.012$), $L/4$ ($p = 0.013$) and $L/6$ ($p = 0.016$) rhythm proved to be statistically significant after Bonferroni modification. The periodic regression applied to the plexogram was able to explain 79% of the 'variance' of transformed predatory data, as shown in figure 3.

Discussion

The estimated predatory activity of the mite species studied culminates around the 7th and 24th days of the lunar cycle, with nadirs around the times of the full moon and of the new moon. In most cases where synodic lunar periodicity has been reported, the peaks of activity of insects were noted in the period around the full moon, often with secondary peaks at the new moon. Such a pattern of lunar rhythm has been found, for example, in the emergence of the African midge, *Chironomus brevibucca*[3], the mayflies *Povilla adusta*[1] or *Clunio marinus*[8], in pit-building activity of larvae of *Myrmeleon obscurus*[5], and partially in the flight activity of moths[6]. Such patterns are usually due to moonlight.

Youthed and Moran[5] discussed synodic lunar periodicity as the combination of a lunar (or tidal) rhythm with the usual solar-day rhythm, or as the combination of both these rhythms. In our case, however, the mites were reared in the absence of moonlight. Hence, the observed periodicity in the predatory activity of mites must be correlated with changes either in the gravitational or – more probably – in the geomagnetic influence of the moon, or else it must be endogenous. The latter has already been shown in myrmeleontid larvae[5], in which moonlight was shown to act only as the phase-setting factor for an endogenous rhythm. However, as the mites were transferred from low outdoor temperatures to the laboratory at the same time, we also have to consider the change of temperature as a factor which may contribute to the periodicity in predatory activity. A further experiment has been planned to verify the existence of lunar periodicity: the mites will be transferred from the overwintering localities to the laboratory on different days of the lunar cycle.

If we confirm our hypothesis about the dependence of mite predatory activity on the lunar cycle we can conclude that physiological cyclical changes exist which condition this phenomenon. A similar theory about interdependence of the flight activity of honey bees and glycemia has been discussed[11]. Of course, other variables, such as locomotor activity, prey preference and resistance to pesticides could be under the influence of the lunar cycle, and this might be of importance in the population dynamics of *T. pyri* in the field. An extension of the experiments will be necessary to verify this hypothesis.

1 Hartland-Rowe, R., Nature, Lond. *176* (1955) 657.
2 Corbet, P. S., Nature, Lond. *182* (1958) 330.
3 Fryer, G., Bull. ent. Res. *50* (1959) 1.
4 Kerfoot, W. B., Anim. Behav. *15* (1967) 479.
5 Youthed, G. J., and Moran, V. C., J. Insect Physiol. *15* (1969) 1259.
6 Brown, E. S., and Taylor, L. R., J. anim. Ecol. *40* (1971) 767.
7 Ochmke, M. C., Interdisc. Cycle Res. *4* (1973) 319.
8 Neumann, D., Ann. Res. Ent. *21* (1976) 387.
9 Rounds, H. D., Comp. biochem. Physiol. *69* (1981) 293.
10 Rounds, H. D., Comp. biochem. Physiol. *74C* (1983) 373.
11 Mohssine, E. H., Bounias, M., and Cornuet, J.-M., Chronobiologia *17* (1990) 201.
12 Sabelis, M. W., in: Spider Mites, Their Biology, Natural Enemies and Control, vol. 1B, p. 103. Eds W. Helle and M. W. Sabelis. Elsevier, Amsterdam 1975.
13 Mikulecký, M., Kubáček, L., Valach, A., Valachová, A., and Ondrejka, P., Time series analysis including periodic components; manual. Bratislava, Teaching Hospital, Comenius University, 1991.
14 Holland, B. S., and Copenhaver, D. P. M., Biometrics *43* (1987) 417.

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Letters to the Editor

From: Dr. Ian R. Tebbett, Director Forensic Toxicology, Dept of Pharmacodynamics, The University of Chicago, Box 6998, Chicago, Illinois 60680, USA

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Sir,

I refer to the article "Cortinarins in *Cortinarius speciosissimus*? A critical revision", by L. Matthies and H. Laatsch that appeared in the June 1991 edition of Experientia [Vol. 47/No. 6/pp. 634–640], and a very similar paper by the same authors which appeared in October's Mycologia under the title "Fluorescent compounds in *Cortinarius speciosissimus*: investigation for the presence of Cortinarins". I feel that the authors' criticism of the work which Dr. Caddy and myself described in 1984 is over zealous, misleading and unfair.

From methanolic extracts of *Cortinarius* species, we isolated three compounds (the cortinarins) two of which produced toxic responses in mice consistent with reports of toxicity caused by the ingestion of *Cortinarius* mushrooms. On chemical examination, these toxic compounds showed NONE of the properties of orellanin. I think it was reasonable to infer from this observation that *Cortinarius* species contain toxic compounds in addition to orellanin. Nonetheless, this seemingly innocuous statement which we first made in 1982, created an uproar from certain members of the European mycological community and the work has been the subject of ridicule ever since. For some reason, which escapes me, research grants are still being used almost 10 years later, for the purpose of disproving the possibility that toxic polypeptides may be present in these fungi.

Matthies and Laatsch state that flourescence in extracts of *C. speciosissimus* MUST be attributed to decomposition products of orellanin and to steroids, and could not possibly be associated with peptides. Their reasoning is based on so-called decisive errors in the structure elucidation of the peptides. I agree entirely that the cleavage of the cyclic peptide is difficult to explain, but this is what happened and we reported our findings.

The NMR spectrum, which was not published but was represented in my thesis, is criticized at length being used as proof that the structure elucidation of the cortinarins was incorrect. In fact, my thesis clearly states that the 90 MHz NMR spectrum was poorly resolved, and merely indicated the presence of a methoxy group, aromatic region and N-H. Unfortunately, I did not have the benefit of a Fourier Transform instrument.

The fact that I reported the isolation of 3 mg of indole from a hydrolysate is criticized because this exceeds the theoretical yield.This isolation requires several steps including preparative TLC and separation on a Sephadex column. It is little wonder that the final weight did not match up to the theoretical yield, but again this is what I found.

Based on the analytical findings of myself and others in the research group we published the most PROBABLE structure of the cortinarins as cyclic polypeptides. I fully accept that minor revisions to the structure may be appropriate. However the points outlined by Matthies and Laatsch are hardly decisive!

In fact the articles by these workers have taken isolated points from our work and presented them out of context. Indeed they identified steroids in ether extracts of the fungi. This is very interesting but in the work in which we described the presence of polypeptides, the ether extracts were simply used as a clean-up stage and were discarded. The methanolic extraction is more interesting; the authors isolated fractions which gave reactions with either cinnamaldehyde/HCl or ninhydrin. Analysis of these fractions failed to show the presence of cortinarins. This does not surprise me since the cortinarins do not react with either compound.

I have some further criticisms of this paper: in the results and discussion section it is stated that, based on Rf values and reaction with acidic ninhydrin, grzymalin and benzonin were found and these were presumably identical to Tebbett's Cortinarins A and C respectively. This is an