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Effect of photoperiod on the biomass and survivorship of juvenile scorpions *Jaguajir rochae* (Scorpiones, Buthidae)

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ABSTRACT. Photoperiod is an important environmental characteristic involved in the regulation of circadian physiological processes in living organisms. This experiment verified the effect of photoperiod on biomass gain and mortality in juvenile scorpions of the species *Jaguajir rochae* (Borelli, 1910). We maintained the juvenile scorpions under two different photoperiod conditions; group A under a light and dark cycle (LD) 12L:12D (n = 36), and group B (n = 35) was subjected to a total dark cycle 0L:24D. Each juvenile was fed cockroaches twice a week and weighed every 15 days until 120th day. We analyzed the relationship between body mass and time, as well as the mortality between groups. Our results showed that group B had a lower biomass gain than that did group A, and no difference in mortality between the two groups was found. Since the locomotory activity of scorpions is associated with a decrease in luminosity, we suggest that group B had a lower gain in biomass due to a higher locomotor activity, resulting in greater energy expenditure. Though our data showed high mortality across both groups, it was not attributed to the photoperiod but to the high mortality rate of the scorpions of this genus during their initial instars and to them being R-strategist organisms. Thus, this study is important for understanding the relationship between photoperiod and biomass gain in invertebrates, especially in scorpions.

Keywords: arthropods; Caatinga; physiology; photoperiodism; semiarid.

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Introduction

The ability to regulate rhythmic processes through zeitgebers or synchronizers is preserved throughout the evolution of organisms (Beck, 1980), with photoperiod and thermoperiod as the most important zeitgebers, influencing many functions in an organism (Beck, 1980; Mishra, Nayak, & Samal, 2019). For example, in arthropods, photoperiod is involved in daily circadian mechanisms that regulate physiological functions and ecological adaptations (Beck, 1980; Goettel & Philogène, 1978; Kannan, Reveendran, Hari Dass, Manjunatha, & Sharma, 2012), wherein alterations to these synchronizers can cause a slower growth rate in some insects (Cayrol, 1975; Danilevskii, Johnston, & Waloff, 1961; Geyspitz, 1953). In a species of scorpion *Gigantometrus swammerdami* (Simon, 1872) these synchronizers can influence groups of neurosecretory cells that are involved in ecdysis and water regulation (Rao & Habibula, 1973). Additionally, the relationship between photoperiod and thermoperiod is a factor of stress and has implicated an oviposition behavior that decreases with constant light and temperature regimes in collembolan *Orchesella cincta* (Linnaeus, 1758) (Liefting, Cosijn & Ellers, 2017). Goettel and Philogène (1978) suggested that the dark period is more important than the light period, and reported that it influences the development of moth *Pyrrharctia isabella* (J. E. Smith, 1797), a nocturnal feeder.

Despite the importance of synchronizers in many arthropod groups, such as arachnids, the biological rhythms have not received much attention, with studies being concentrated on locomotor activity and physiological rhythms (Cloudsley-Thompson, 1978). Studies, mainly locomotory, on the Order Scorpiones, were limited because about 67% of them were conducted on a single species, the *Chersonesometrus fulvipes* (C. L. Koch, 1837) (Warburg, 2013). Scorpions' biological rhythm ensures that they stay in total darkness during the day, allowing them to be sheltered (Cloudsley-Thompson, 1978). In these animals, an increase in natural illumination by the moon can cause a decrease in foraging behavior, possibly because the illuminated night in the field can make the species more vulnerable to predation (Skutelsky, 1996).

Therefore, in this study, we speculated that juvenile scorpions of *Jaguajir rochae* (Borelli, 1910), which are large in size (50–100 mm), abundant, and widely distributed in the Caatinga vegetation in the Brazilian northeast region (Esposito, Yamaguti, Souza, Pinto-da-Rocha, & Prendini, 2017; Lira, De Souza, & Albuquerque, 2018), may be more active during all or most of the time under a full dark regime than those under a normal light-dark cycle. To the best of our knowledge, no study has investigated the effects of photoperiod on body mass and mortality rate in scorpions. This study aimed to verify the effect of photoperiod on the biomass and survivorship using *J. rochae* as a study system.

Material and methods

Effects of photoperiod on biomass and mortality

The experiment was performed with 71 juvenile scorpions in the 2nd instar from three females collected in a Caatinga vegetation in the village of Ameixas (8°06′11″ S, 35°46′30″ W), Municipality of Cumaru, Pernambuco State, Brazil. All groups were maintained in a laboratory at the *Universidade Federal de Pernambuco*. The juvenile specimens were individualized into plastic terrariums (14 × 10 × 8 cm) with pieces of cardboard for shelter and cotton wool soaked in water at 24 ± 2°C, 70 ± 5% relative humidity. All scorpions were fed at night (6:00pm-7:00pm) with cockroaches *Nauphoeta cinerea* (Oliver, 1789), approximating 0.2 ± 0.1 g twice per week. The juveniles were randomly divided into two different photoperiods, wherein group A (n = 36) was subjected to a light and dark (LD) cycle 12L:12D, and group B (n = 35) was subjected to a total dark cycle 0L:24D. The animals were weighed at night every 15 days until the 120th day of observation, under red light using an Analytical Balance model AUW220D, Shimadzu, Barueri, São Paulo State, Brazil. At end of experiment juveniles reached the 3rd – 4th instar and none sexual dimorphism in species was noted (see Esposito et al., 2017). To analyze the influence of photoperiod on mortality, all occurrences of death were recorded. All voucher specimens were deposited in the Arachnological Collection of *Universidade Federal de Pernambuco*.

Data analyses

Correlation analyses were used to verify the relationship between body mass and time (every 15 d) in both groups (groups A and B). In this analysis, body mass was expressed by subtracting the body mass value recorded in a week from that of the previous week. Comparisons between the body mass of the groups (15, 30, 45, 60, 75, 90, 105, and 120th day) were performed using the Kruskal–Wallis test using PAST 3.14 software for windows (Hammer, Harper, & Ryan, 2001). For mortality analysis, we used the log-rank (Mantel-Cox) test to assess survival between the groups, which was performed using GraphPad Prism version 8.0.0 for Windows, GraphPad Software, San Diego, California, USA.

Results

The observations were performed until 120th day because of the high mortality rate of juveniles. The juveniles of group A exhibited a gain in body mass until the first 60th day of observations, while animals from group B exhibited a gain in body mass until the 45th day (Figure 1). However, group A animals showed a significantly higher ($H = 518.2$, $p < 0.0001$) gain in body mass compared to that of group B throughout the experiment (group A = 0.0028 ± 0.0051 g; group B = 0.0021 ± 0.0028 g). Scorpions from group A exhibited one peak of mortality at 75–90th day that represented 27,78% (n = 10) individuals of this group, while group B exhibited three peaks at 1st –15th (n = 9), 75–90th (n = 7), and 105–120th day (n = 3). Despite these, no differences were found through the log-rank (Mantel-Cox) test ($p = 0.1957$) for the mortality rate between the groups (Figure 2).

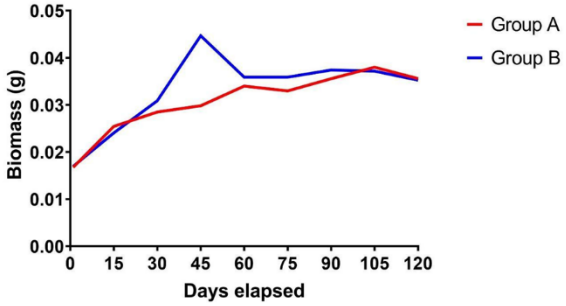

Figure 1. Body mass of the scorpions *Jaguajir rochae* (Borelli, 1910), at experimental conditions, group A under 12L:12D and group B under 0L:24D).

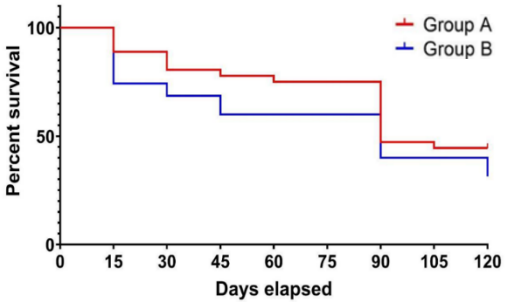

Figure 2. Survival curves of the juvenile scorpions *Jaguajir rochae* (Borelli, 1910), at experimental conditions, group A under 12L:12D and group B under 0L:24D).

Discussion

Our results showed a considerable relationship between weight gain and photoperiod in scorpion development. Group B, which was reared in darkness, had a slower weight gain and showed a peak fall in weight gain starting from the 45th day, while group A, which was reared in 12L:12D, showed a peak fall only on the 60th day. Previous studies on a caterpillar, *Pterourus* (*Papilio*) *glaucus* (Linnaeus, 1758), also showed a slower growth under total darkness than those that were placed under a different photoperiod (12L:12D and 16L:8D) (Muehlhaus & Scriber, 2006). Similarly, in this study, *J. rochae* reared in darkness had a slow mass gain, and their survival showed a non-significant difference compared to that of the individuals kept under natural conditions. According to Muehlhaus and Scriber (2006), the larval stage in *P.* (*P.*) *glaucus* exhibits a compensatory response and that this behavior and the physiological adjustments for rapid growth in the feeding of neonates is a response to longer periods of experimental stress such as low temperatures, poor host plant conditions, and long periods under total darkness. In our findings, after the 60th day, group B had compensatory gain weight, reaching the biomass of group A, suggesting an adaptation. Therefore, this possibly occurred as a result of an energy-saving mechanism, which was a consequence of the decreased activity. Furthermore, this may indicate the anticipation of the scorpions for these environmental conditions, as a result of the regulation of the circadian rhythms and this system's fundamental role in the initiation and interruption of the activities of organisms (Cruz, 2007).

Scorpions, in general, have decreased activity with conditions of increased brightness (Polis, 1979; 1990; Brown & O'Connell, 2000); thus, we hypothesized that the absence of light as well as any natural alteration could directly affect the development of scorpions. In our experiments, the change in the photoperiod affected group B more, and they had a lower overall biomass gain due to the absence of exposure to light. We suggest that the increased stress conditions in group B was an important factor in this physiological change, given that scorpions can increase their activity time, culminating in greater energy expenditure in these laboratory conditions.

Additionally, in our experiments, we found no differences in the mortality between groups A and B, with both groups showing a high juvenile scorpion mortality. At the end of the experiment were registered a total of 21 (58.33%) deaths in group A and 24 (68.57%) in group B. Indeed, the initial instars present a high mortality rate (Sarmento, Souza, Meiado, & Albuquerque, 2008). This is particularly true in species of the genus *Jaguajir* (Esposito et al., 2017), which produces a large number of small young individuals (Sarmento et al., 2008). This indicates that scorpions of this genus invest in quantity instead of quality, classifying them as R-strategists. R-strategist species can explore temporary resources, exhibiting high ecological plasticity (Southwood, 1962; Begon, Townsend, & Harper, 2006). Our assumptions may be supported by the strong seasonality of the habitat of *J. rochae* (Caatinga vegetation) and by their wide range of colonized microhabitats (Esposito et al., 2017; Lira et al., 2018). Therefore, the high mortality found in our study could not be attributed to the photoperiod. Similar to that described for tick, *Amblyomma maculatum* Koch, 1844 wherein different photoperiods indicated that survival could not be attributed to the effects of light and dark periods (Lohmeyer, Pound, & George, 2009).

Even with the evidence that the circadian rhythm in organisms is composed of several circadian oscillators, the structure and interaction of this system with the environment are poorly understood, especially for invertebrate organisms because studies are concentrated on vertebrates, specifically, on mammals (Cruz, 2007).

Conclusion

With this study, it was possible to better understand how the alteration in photoperiod is connected to weight gain and mortality in scorpions. The results obtained from this study could be used for future research that seeks to understand the expression and functioning of circadian regulation mechanisms and how luminosity interferes in different organisms.

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References

Beck, S. D. (1980). *Insect photoperiodism*. (2nd ed.). London, UK: Academic Press.

Begon, M., Townsend, C. R., & Harper J. L. (2006). *Ecology: from individuals to ecosystems*. (4th ed.). Oxford, UK: Blackwell.

Brown, C. A., & O'Oconnell, J. D. (2000). Plant climbing behavior in the scorpion *Centruroides vittatus*. *The American Midland Naturalist*, *144*(2), 406-418. DOI: https://doi.org/10.1674/00030031(2000)144[0406:pcbits]2.0.co;2

Cayrol, R. (1975). Influence de diverses combinaisons des photophases de 8 heures et 16 heures sur le processus de development et de croissance chez les larves d'Amathes *C. nigurm* (Lep. Noctuidae). *Annales de Zoologie Ecologie Animale*, *7*(2), 321-330.

Cloudsley-Thompson, J. L. (1978). Biological clocks in Arachnida. *Bulletin of the British Arachnological Society*, *4*(4), 184-191.

Cruz, J. G. P. (2007). Ritmo circadiano e atividade locomotora em *Bothrops jararacussu* (Serpentes, Viperidae). *Biotemas*, *20*(3), 55-61. DOI: https://doi.org/10.5007/%25x

Danilevskii, A., Johnston, J., & Waloff, N. (1961). *Photoperiodism and seasonal development of insects*. Edinburgh, UK: Oliver & Boyd.

Esposito, L. A., Yamaguti, H. Y., Souza, C. A., Pinto-da-Rocha, R. & Prendini, L. (2017). Systematic revision of the Neotropical Club-Tailed Scorpions, *Physoctonus*, *Rhopalurus*, and *Troglorhopalurus*, revalidation of *Heteroctenus*, and descriptions of two new genera and three new species (Buthidae: Rhopalurusinae). *Bulletin of the American Museum of Natural History*, *415*(1), 1-136. DOI: https://doi.org/10.1206/0003-0090-415.1.1

Geyspitz, K. F. (1953). Reactions of mono-voltine butterflies to prolongation of daylength. *Entomologicheskoe Obozrenie*, *33*(1), 17-31.

Goettel, M. S. & Philogène, B. J. R. (1978). Effects of photoperiod and temperature on the development of a univoltine population of the banded woollybear, *Pyrrharctia* (*Isia*) *isabella*. *Journal of Insect Physiology*, *24*(6-7), 523-527. DOI: https://doi.org/10.1016/0022-1910(78)90053-7

Hammer, Ø., Harper, D. A. T. & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia electronica*, *4*(1), 1-9.

Kannan, N. N., Reveendran, R., Hari Dass, S., Manjunatha, T., & Sharma, V. K. (2012). Temperature can entrain egg laying rhythm of *Drosophila* but may not be a stronger zeitgeber than light. *Journal of Insect Physiology*, *58*, 245-255. DOI: https://doi.org/10.1016/j.jinsphys.2011.11.012

Liefting, M., Cosijn, J., & Ellers, J. (2017). Synergistic effect of daily temperature fluctuations and matching light-dark cycle enhances population growth and synchronizes oviposition behavior in a soil arthropod. *Journal of Insect Physiology*, *96*, 108-114. DOI: https://doi.org/10.1016/j.jinsphys.2016.10.002

Lira, A. F. A., De Souza, A. M., Albuquerque, C. M. R. (2018). Environmental variation and seasonal changes as determinants of the spatial distribution of scorpions (Arachnida: Scorpiones) in Neotropical forests. *Canadian Journal of Zoology*, *96*(9), 963-972. DOI: https://doi.org/10.1139/cjz-2017-0251

Lohmeyer, K. H., Pound, J. M., & George, J. E. (2009). Effects of photoperiod on reproduction, nymphal developmental timing, and diapause in *Amblyomma maculatum* (Acari: Ixodidae). *Journal of Medical Entomology*, *46*, 1299-1302. DOI: https://doi.org/10.1603/033.046.0607

Mishra, C. S. K., Nayak, S., & Samal, S. (2019). Low intensity light effects on survivability, biomass, tissue protein and enzyme activities of the earthworm *Eudrilus eugeniae* (Kinberg). *Invertebrate Survival Journal*, *16*(1), 8-14. DOI: https://doi.org/10.25431/1824-307X/isj.v0i0.8-14

Muehlhaus, J., & Scriber, J. M. (2006). Compensatory feeding and growth responses of *Papilio glaucus* (Lepidoptera: Papilionidae) larvae reared in darkness. *Great Lakes Entomologist*, *39*(3-4), 1-7.

Polis, G. A. (1979). Prey and feeding phenology of the desert sand scorpion *Paruroctonus mesaensis* (Scorpionidae: Vaejovidae). *Journal of Zoology*, *188*(3), 333-346. DOI: https://doi.org/10.1111/j.1469-7998.1979.tb03419.x

Polis, G.A. (1990). *The biology of scorpions*. Stanford, CA: Stanford University Press.

Rao, K. P., & Habibulla, M. (1973). Correlation between neurosecretion and some physiological functions of the scorpion *Heterometrus swammerdami*. *Proceedings of the Indian Academy of Sciences* - Section B, *77*(4), 148-155.

Sarmento, S. M. N., Souza, A. M., Meiado, M. V., & Albuquerque, C. M. R. (2008). Notes on the life history traits of *Rhopalurus rochai* (Scorpiones, Buthidae) under different feeding regimes. *Journal of Arachnology*, *36*(2), 476-479. DOI: https://doi.org/10.1636/csh07-122.1

Skutelsky, O. (1996). Predation risk and state-dependent foraging in scorpions: Effects of moonlight on foraging in the scorpion *Buthus occitanus*. *Animal Behaviour*, *52*(1), 49-57. DOI: https://doi.org/10.1006/anbe.1996.0151

Southwood, T. R. E (1962). Migration of terrestrial arthropods in relation to habitat. *Biological Reviews*, *37*(2), 171-211. DOI: https://doi.org/10.1111/j.1469-185X.1962.tb01609.x

Warburg, M. R. (2013). The locomotory rhythmic activity in scorpions: with a review. *Arthropods, 2*(3), 95-104.