BRILL

Animal Biology 62 (2012) 289–299

Animal Biology
brill.nl/ab

Activity patterns of the Brown Vine snake *Oxybelis aeneus* (Wagler, 1824) (Serpentes, Colubridae) in the Brazilian semiarid

Paulo C.M.D. Mesquita*, **Diva M. Borges-Nojosa**, **Daniel C. Passos and Castiele H. Bezerra**

Universidade Federal do Ceará (NUROF-UFC), Campus do Pici, Bloco 905, 60455-760, Fortaleza, Ceará, Brazil

Accepted: September 26, 2011

Abstract
The Brown Vine snake, *Oxybelis aeneus* (Wagler, 1824), is widely distributed from the United States to Argentina. 113 specimens encountered in the field and 39 individuals from scientific collections were analyzed and we determined patterns of diet, habitat use, and daily and seasonal activity. *Oxybelis aeneus* can be found to be active year round, especially during the dry and warmer months. Daily temperature poorly describes its activity as it seems to be more active around 31 to 35°C. During the hours of inactivity the species tends to chose higher branches than when active. The snakes choose spiny trees as retreat sites and spineless trees as foraging sites. We suggest that the high abundance of *O. aeneus* makes it an appropriate model organism for studies on activity patterns of snakes in semi-arid environments.
© Koninklijke Brill NV, Leiden, 2012.

Keywords
Squamata; arboreality; seasonality; diet; caatinga

Introduction

The activity patterns of snakes vary in temporal and spatial scales, and these variations may be influenced by both biotic and abiotic factors (Gibbons and Semlitsch, 1987). Climate variables, such as rainfall, humidity and temperature are among the most influential abiotic factors affecting snakes activity (Lillywhite, 1987; Huey et al., 1989; Crews et al., 1993; Pough et al., 2004). As ectothermic animals, snakes

*) Corresponding author; e-mail: paulocmdm@gmail.com

© Koninklijke Brill NV, Leiden, 2012 DOI 10.1163/157075611X618228

are particularly sensitive to temperature changes, especially in temperate environments, where most of the studies on activity patterns were conducted. In general, temperature is the main climatic factor responsible for patterns of activity of the species (Gibbons and Semlitsch, 1987; Shivik et al., 2000; Krysko, 2002; Willson and Dorcas, 2004; Winne et al., 2005). Marques et al. (2000) and Sawaya et al. (2008) suggested that the majority of the snakes from some tropical areas in Brazil has its annual peak of activity during the warmest and rainiest months, when probably there is a greater availability of prey. However, in many tropical areas temperature variation over the year is not remarkable and rainfall has a greater influence on the activity of snakes (Brown et al., 2002; Brown and Shine, 2002, 2005).

Daily activity is an important and poorly studied aspect of life history of snakes. Especially in the Neotropics, most species are classified as diurnal or nocturnal without major quantitative data on the hours they are active and inactive (Vitt and Vangilder, 1983; Martins and Oliveira, 1999; Oliveira and Martins, 2001). The activity of some species may be concentrated at certain times of day depending on factors such as temperature, prey availability, predator avoidance, light intensity, evolutionary history and other factors that have not yet been clarified (Llewelyn et al., 2006; Pizzato et al., 2008).

Habitat selection by animals is defined as the choice of an area over a variety of alternatives, in the absence of restrictions (Partridge, 1978). Obviously, no area is free of restrictions, and according to Ward and Lubin (1993), habitat selection is related to the physical environment, availability of food, the presence of predators and physiology. Historically, most of the studies on habitat selection in Squamata, are directed to wards lizards, especially arboreal species, because they are easier to be accompanied, while most snakes have secretive habits and many seek shelters that can hardly be accessed by humans, as canopy or underground shelters. Probably that is the reason why snakes have received less attention (Kiester et al., 1975; Vitt et al., 1981; Reinert, 1993; Downes and Shine, 1998; Reaney and Whiting, 2003).

The Vine-snake *Oxybelis aeneus* (Wagler, 1824) (fig. 1) is a long and slender colubrid snake widely distributed from south of Arizona, USA, to southern Brazil (Goldberg, 1998). The available data on *O. aeneus* focuses mainly on reproduction, sexual dimorphism and anecdotal notes on activity (Keiser, 1967; Henderson, 1974; Franzen, 1996; Goldberg, 1998, 2005; Mesquita et al., 2010, Mesquita et al., 2010). Herein we present information on patterns of diet, seasonal activity, daily activity and habitat selection by *O. aeneus* in a semi-arid region in northeastern Brazil.

Material and methods

Data on the activity patterns of *O. aeneus* were obtained during monthly visits, from January 2008 to December 2009, to a semiarid area (3°49′06, 1″S, 39°20′14, 8″W, GPS Datum: WGS 84), in Pentecoste municipality, State of Ceará, Brazil, and by analyses of specimens deposited in Herpetological Collection of Federal University of Ceará (CHUFC) collected in the study area and surroundings.

Figure 1. Brown Vine snake, *Oxybelis aeneus*, showing a defensive behavior.

Field data

The snakes were found by time constrained search (TCS), consisting of three people slowly walking in tracks in search for snakes in the study area. We did 24 hours of TCS per trip (16 hours daytime and 8 hours night), totaling 576 hours per person. The search effort was homogenously distributed between 7 a.m. and 6 p.m. The interval between 7 p.m. and 12 a.m. was unevenly sampled with most of the effort occurring between 7 and 10 p.m. This bias is unlikely to strongly influence our results as *Oxybelys aeneus* is reported to be diurnal (Henderson, 1974; Vitt and Vangilder, 1983; Franzen, 1996), and we would expect most of the individuals to be inactive at night. For each observed specimen we recorded date, time, substrate used, substrate height estimated by comparison with known objects, and status of activity (active or resting). We considered "active" thise snakes that were observed moving or in state of alertness, with the head not touching the substrate; and "resting" when the snake was not moving, curled, with its head touching its own body or the substrate, showing slow or no reaction to our approach and touch (Martins and Oliveira, 2001). All spotted animals were captured by hand, marked by scale-cliping, individuals presenting evident stomach contents were forced to regurgitate by gentle ventral palpation (Fitch, 1987), and released on the site of capture.

We considered as "arboreal" any snake found higher than 0.5 m and "terrestrial" any snake observed on the ground or lower than 0.5 m.

Climatologic data

In the study area, the historical annual means are 27.1°C, 74% relative humidity and 797.0 mm rainfall, presenting a remarkable seasonality with rainfall concentrated between February and June (Aguiar et al., 2004). Data on monthly rainfall and monthly mean temperature for the study period were provided by the State Bureau of Meteorology – Fundação Cearense de Meteorologia (FUNCEME). Mean daily air temperatures were calculated monthly based on temperatures collected hourly with a digital thermometer during the field trips.

Museum data

Specimens collected in the semi-arid area were dissected to record food items. Some specimens had records in the registry book regarding time of collection, activity and substrate use, however we did not use this information, as there were no details about the methods employed to collect them.

Analysis

Linear correlation test was used to evaluate the association between rainfall and monthly mean temperature (T_{mean}) with the number of snakes found monthly and a partial correlation test to evaluate if the variables influenced the seasonal activity independently, all data were transformed to their natural log. To analyze the difference in height between the substrate used by active and inactive snakes, we used the Mann-Whitney U test (two tailed) and the type of substrate used (spiny or non-spiny) during activity and inactivity through Chi-square test.

To determine the patterns of daily activity we used a linear correlation of the mean temperature during each time interval against the abundance of active snakes found, all data were log transformed. We excluded the intervals between 6 a.m. and 7 a.m. from the analysis because most of the snakes found during this period were resting.

Results

We analyzed a total of 152 specimens, 113 sampled in the field and 39 from the CHUFC. As only one recapture was made we excluded the information of the recapture from all analysis.

Diet

We obtained 25 dietary items from 21 individuals (10 in field and 11 from museum specimens): 24 prey were lizards of five species, and one was a frog. Most snakes fed on a single prey, but three preyed on two items, and one preyed three newborn *Mabuya heathi*. The species *Cnemidophorus ocellifer* and *Tropidurus hispidus* were recorded 8 times each and were the most frequent prey (table 1).

Table 1.
List of food items found in *Oxybelis aeneus* in this study.

Prey category	Family	Species	N1	N2	RF (%)
Lizards					96
	Teiidae	*Cnemidophorus ocellifer*	7	8	32
	Tropiduridae	*Tropidurus hispidus*	8	8	32
	Scincidae	*Mabuya heathi*	2	4	16
	Gekkonidae	*Hemidactylus mabouia*	1	1	4
	Unidentified	Unidentified	3	3	12
Frogs					4
	Leptodactylidae	*Leptodactylus fuscus*	1	1	4
Total					100

N1: Number of specimens presenting the item, N2: Number of times the item was found, RF: Relative frequency of the item.

Activity patterns

We captured active snakes during all months of the year with most of the activity during the dry season, from July to January (fig. 2). We found positive association between snake abundance and T_{mean} ($r = 0.6364$; $df = 10$; $P = 0.026$) and negative association with rainfall ($r = -0.6616$; $df = 10$; $P = 0.019$). But when we removed the effect of rainfall, we found no significant influence of T_{mean} ($rXY.Z = 0.1351$; $df = 9$; $P = 0.6921$) similarly, when we removed the effect of T_{mean} we found no significant influence of rainfall on the abundance of *O. aeneus* ($rXY.Z = 0.5814$; $df = 9$; $P = 0.0606$).

Daily activity occurred almost exclusively during the day, between 4:50 h and 18:00 h, corresponding to approximately 99.12% of the records. We found a single individual (0.88%) active at night at 22:15 h. Besides this, the other 50 individuals recorded during the night, between 18:10 h and 4:14 h were resting. We found no snakes resting during the day. Two peaks of daily activity were observed during the day. We found 59.25% of the active *O. aeneus* in the morning peak and 29.62% in the afternoon peak. Most individuals were found active between approximately 31°C and 35°C (fig. 3). Although we found negative association between number of snakes and mean hourly temperature, this result was not statistically significant ($r = -0.331$; $P = 0.349$).

From the 113 *O. aeneus* observed in the study area. 84.07% ($n = 95$) were in arboreal substrate at the time of encounter. The other 15.93% ($n = 18$) that were on the ground attempted to flee to trees when approached.

Active snakes were found at lower heights (mean = 1.104 ± SD 0.907 m high) than inactive individuals (mean = 4.059 ± SD 2.292 m) ($U = 252$, $P < 0.0001$) (fig. 4).

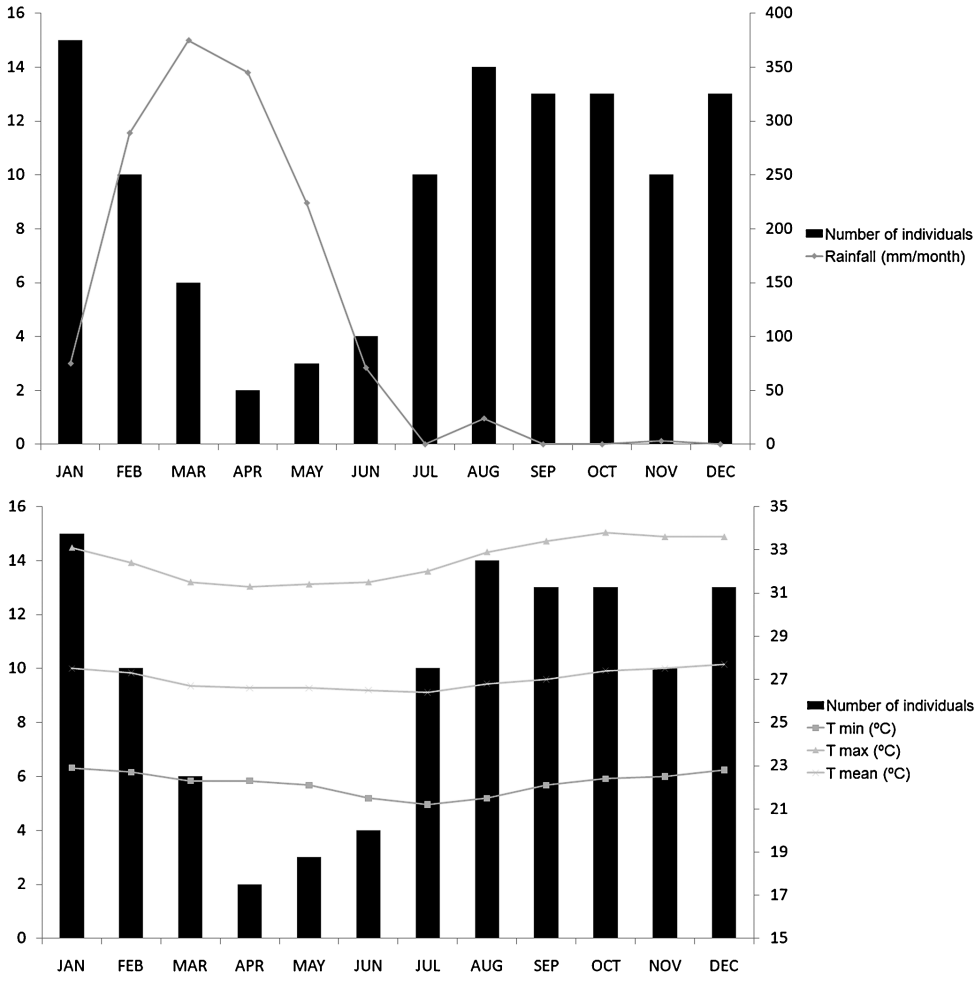

Figure 2. Abundance of *Oxybelis aeneus* in relation to mean monthly temperature (T_{mean}) (A) and rainfall (B) in the study area.

Of the 50 snakes found resting 54% ($n = 27$) were in spiny-trees. When active, only 20.6% ($n = 13$) of the snakes were found using spiny trees (Chi-square = 13.57, $df = 1$, $P = 0.0002$).

Discussion

Sun et al. (2001) considered it appropriate to study the activity patterns only if the organism is a large species, occurring in high density in a relatively open and homogeneous area. The species also should be sedentary, should not avoid human presence and should be easily observable while active and remain hidden during the period of inactivity. In our study area, *O. aeneus* is easily found during activity and

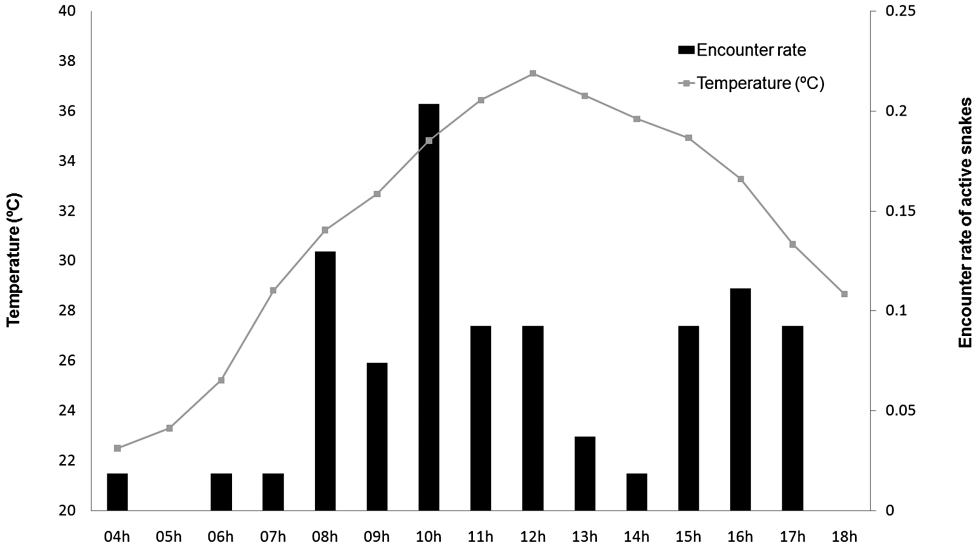

Figure 3. Number of active *Oxybelis aeneus* found at each time interval and mean hourly temperature.

resting periods, presenting virtually all the features suggested by Sun et al. (2001), in spite of being a slender, medium size snake.

According to our results *Oxybelis aeneus* is a specialist predator, feeding mainly on lizards. Keiser (1967) suggested that *O. aeneus* also prey on birds and insects. No snakes studied here contained birds in their digestive tract, and although we found some insects they were always associated with the presence of other prey, probably representing secondary content from the main prey.

The pattern of seasonal activity of snakes can vary depending on phylogenetic, ecological (such as reproductive activity and food availability) and environmen-

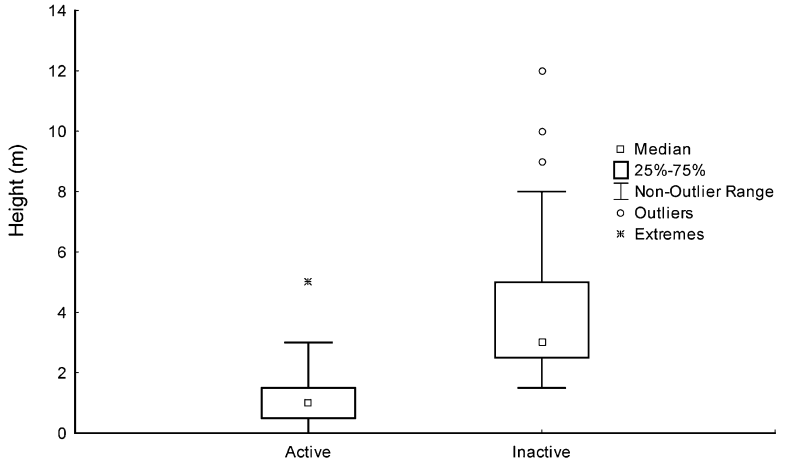

Figure 4. Heights of the branches used by active and inactive *Oxybelis aeneus*.

tal factors (Henderson et al., 1978; Oliveira and Martins, 2001; Brown and Shine, 2002).

No association between activity and temperature was expected because in the Brazilian semi-arid are, as in other tropical areas, there is only a little temperature variation during the year, as a result, rainfall was expected to be the most important fluctuating climatic variation affecting animals activities (Vitt and Goldberg, 1983). Although the T_{mean} fluctuation is in fact small (around 1.3 degrees year round), we observed that it is an important factor affecting the seasonal activity of *O. aeneus* when combined with rainfall. The positive association with T_{mean} and negative association with rainfall demonstrate that the activity pattern of *O. aeneus* is of an extensive period of activity, with marked decrease when temperatures are low and rainfall is high, being more intense during the dry and warmer season. We also observed that temperature and rainfall are not completely independent factors, so our results are consistent with the finding of Brown and Shine (2002) that snake activity is influenced due to a combination of seasonal changes in temperature, rainfall and other unmeasured variables such as prey availability, for example.

The higher activity during periods of low water stress is unexpected for most organisms. The pattern observed for *O. aeneus* may be related to prey activity, as lizards are more active during the dry season or to evolutionary traits related to predator avoidance as the snake body shape resembles to a dry tree branch (Greene, 1988; Vitt, 1995).

Franzen (1996) found active *O. aeneus* only during daytime but did not mentioned patterns of daily activity. Surprisingly, we found no significant association between short-term changes in daily temperature and snake activity. Our data suggests a thermal preference of 31-35°C, resulting in a bimodal pattern of activity between 8-12 a.m. and 3-6 p.m. Brown and Shine (2002) also found that short-term factors were poor in predicting snake encounters. The reason for this may reside in ectothermy as the snakes may not respond to temperature changes immediately, so analysis investigating time-lagged or non-linear response to the variables might reveal clearer results.

In relation to habitat selection, we confirmed the results previously obtained by Henderson (1974) and Franzen (1996): most individuals of *O. aeneus* present arboreal habits. We also confirmed Henderson's (1974) hypothesis that this species seeks mainly spiny trees as retreat sites, because this kind of tree offers protection against predators during the resting periods when the snakes are presumably more vulnerable.

Snakes are commonly found in lower branches or on the ground during the activity period. The reason for this may be because it feeds mainly on terrestrial and semi-terrestrial prey such as *Cnemidophorus ocellifer*, *Tropidurus hispidus* and *Mabuya heathi*. Also, with this behavior, the individuals remain less exposed to solar radiation, avoiding overheating.

The choice of higher branches as retreat sites may be related to good thermal sites for *O. aeneus*, which comes into activity in the early hours of the morning.

Thus, the snakes remaining in the upper branches are exposed to sun radiation and able to thermoregulate quickly, as soon as the sun begins to emerge.

Based on the wide range of results for snakes from temperate zones, Gibbons and Semlitsch (1987) suggested that the activity patterns of the Neotropical snake should be considered individually for each species, because in a region with great diversity of species, biomes and climate complexity, it is likely that there are different patterns of seasonal activity among species. A major difficulty to obtain information on activity patterns of snakes is the low number of individuals captured or observed per hour in studies of short duration (Marques et al., 2000), the relatively high population density of *O. aeneus* in the study area makes it an appropriate organism for this type of study.

Conclusions

Oxybelis aeneus is an arboreal and strictly diurnal snake that seems to forage closer to the ground, mostly on lizards and rarely on frogs, and may select higher substrates to rest. It is more often associated to spiny plants, which may confer protection against predators. As observed in other tropical species, these snakes are active most of the year, but even in tropical areas, small variations in temperature and seasonality of rainfall influence their activity patterns. A noticeable decrease in numbers is observed from April to June, when temperature is low and rainfall is high. Their daily activity pattern is bimodal, apparently related to temperatures between 31 and 35°C, suggesting that diurnal snakes in tropical areas have a high thermal tolerance but tend to avoid activity during the hottest times of the day. The reasons for the decrease in number of animals seen during the wet season remains unclear, and it would be very interesting to know if this pattern is common in other snakes in the caatinga and other arid zones.

Acknowledgements

We thank to IBAMA for the license to study snakes in the field (License number: 18596-1), Ligia Prado and an anonymous referee for valuable suggestions on the first versions of the manuscript and FUNCAP for financial support.

References

Aguiar, M.J.N., Viana, T.V.A., Aguiar, J.V., Crisóstomo Jr., R.R., Aquino, F.C. & Barreto Jr., J.H.C. (2004) Dados climatológicos: Estação Pentecoste, 2003. In: M.A.R. Melo (Ed.) *Embrapa Agroindústria Tropical, Documentos*, *87*, pp. 6-17. Embrapa, Fortaleza.

Brown, G.P. & Shine, R. (2002) The influence of weather conditions on activity of tropical snakes. *Austral Ecology*, 27, 596-605.

Brown, G.P. & Shine, R. (2005) Female phenotype, life history and reproductive success in free-ranging snakes (*Tropidonophis mairii*). *Ecology*, 86(10), 2763-2770.

Brown, G.P., Shine, R. & Madsen, T. (2002) Responses of three sympatric snake species to tropical seasonality in northern Australia. *Journal Trop. Ecol.*, 18, 549-568.

Crews, D., Robker, R. & Mendonça, M. (1993) Seasonal fluctuations in brain nuclei in the red-sided garter snake and the hormonal control. *Journal Neurosci.*, 13(12), 5356-5364.

Downes, S. & Shine, R. (1998) Sedentary snakes and gullible geckos: predator-prey coevolution in nocturnal rock-dwelling reptiles. *Anim. Behav.*, 55, 1373-1385.

Fitch, H.S. (1987) Collecting and life-history techniques. In: R.A. Seigel, J.T. Collins & S. Novak (Eds.) *Snakes: Ecology and Evolutionary Biology*, pp. 143-146. Mac Millan Publishing Company, New York.

Franzen, M. (1996) Ökologische und morphologische Aspekte einer costaricanischen Population von *Oxybelis aeneus* (Wagler, 1824) (Serpentes, Colubridae). *Herpetozoa*, 9(4), 121-131.

Gibbons, J. & Semlitsch, R. (1987) Activity patterns. In: R.A. Seigel, J.T. Collins & S. Novak (Eds.) *Snakes: Ecology and Evolutionary Biology*, pp. 396-421. Mac Millan Publishing Company, New York.

Goldberg, S.R. (1998) Reproduction in the Mexican vine snake *Oxybelis aeneus* (Serpentes: Colubridae). *Texas Journal of Science*, 50(1), 51-56.

Goldberg, S.R. (2005) *Oxybelis aeneus* (Brown Vine Snake) reproduction. *Herpetol. Rev.*, 36(1), 70.

Henderson, R.W. (1974) Aspects of the ecology of the neotropical vine snake *Oxybelis aeneus* (Wagler). *Herpetologica*, 30, 19-24.

Henderson, R.W., Dixon, J.R. & Soini, P. (1978) On the seasonal incidence of tropical snakes. *Contributions in Biology and Geology*, 17, 1-15.

Huey, R., Peterson, C., Arnold, S. & Porter, W. (1989) Hot rocks and not-so-hot rocks: retreat site selection by garter snakes and its thermal consequences. *Ecology*, 70, 931-944.

Keiser, E.D. (1967) *A monographic study of the Neotropical Vine Snake,* Oxybelis aeneus *(Wagler, 1824)*. Ph.D. (dissertation), Louisiana State University, 157 pp.

Kiester, A.R., Gorman, G.C. & Arroyo, D. (1975) Habitat selection behaviour of three species of *Anolis* lizard. *Ecology*, 56, 220-225.

Krysko, K.L. (2002) Seasonal activity of the Florida Kingsnake *Lampropeltis getula floridana* (Serpentes: Colubridae) in Southern Florida. *Am. Midl. Nat.*, 148, 102-114.

Lillywhite, H.B. (1987) Circulatory adaptations of snakes to gravity. *Am. Zool.*, 27, 81-95.

Llewelyn, J., Shine, R. & Webb, J. (2006) Time of testing affects locomotor performance in diurnal versus nocturnal snakes. *J. Therm. Biol.*, 31, 268-273.

Marques, O.A.V., Eterovic, A. & Endo, W. (2000) Seasonal activity of snakes in the Atlantic forest in southeastern Brazil. *Amphibia-Reptilia*, 22, 103-111.

Goldberg, S.R. (1998) Reproduction in the Mexican vine snake *Oxybelis aeneus* (Serpentes: Colubridae). *Tex. J. Sci.*, 50(1), 51-56.

Greene, H.W. (1988) Antipredator mechanisms in reptiles. In: C. Gans & R.B. Huey (Eds.) *Biology of the Reptilia*, *Volume 16, Ecology, Defense and Life History*, pp. 1-152. Alan R. Liss, Inc., New York.

Martins, M. & Oliveira, E.M. (1999) Natural history of snakes in forests of the Manaus region, Central Amazonia, Brazil. *Herpetol. Nat. His.*, 6(2), 78-150.

Mesquita, P.C.M.D., Borges-Leite, M.J., Borges-Nojosa, D.M. & Passos, D.C. (2010) *Oxybelis aeneus* (Brown Vinesnake) reproduction. *Herpetol. Rev.* 41, 346.

Mesquita, P.C.M.D., Borges-Nojosa, D.M. & Bezerra, C.H. (2010) Dimorfismo sexual na "cobra-cipó" *Oxybelis aeneus* (Serpentes, Colubridae) no Estado do Ceará, Brasil. *Biotemas*, 23(4), 65-69.

Oliveira, E.M. & Martins, M. (2001) When and where to find a pitviper: activity pattern and habitat use of the lancehead, *Bothrops atrox*, in central amazonia, Brazil. *Herpetol. Nat. His.*, 8(2), 101-110.

Partridge, L. (1978) Habitat selection. In: J.R. Krebs & N.B. Davies (Eds.) *Behavioural Ecology: An Evolutionary Approach*, pp. 351-376. Sinauer Associates, Sunderland, Massachusetts.

Pizzatto, L., Child, T. & Shine, R. (2008) Why be diurnal? Shifts in activity time enable young cane toads to evade cannibalistic conspecifics. *Behav. Ecol.*, 19, 990-997.

Pough, F.H., Janis, C.M. & Heiser, J.B. (2004) *Vertebrate Life*. 7th ed. Pearson Prentice Hall Publishing, Saddle River, NJ.

Reaney, L.T. & Whiting, J.M. (2003) Picking a tree: habitat use by the tree agama, *Acanthocercus atricollis atricollis*, in South Africa. *African Zoology*, 38(2), 273-278.

Reinert, H.K. (1993) Habitat selection in snakes. In: R.A. Seigel & J.T. Collins (Eds.) *Snakes: Ecology and Behaviour*, pp. 201-240. McGraw-Hill, New York.

Sawaya, R.J., Marques, O.A.V. & Martins, M. (2008) Composition and natural history of a Cerrado snake assemblage at Itirapina, São Paulo state, southeastern Brazil. *Biot. Neotrop.* 8, 129-151.

Schimidt-Nielsen, K. (2002) *Fisiologia Animal: Adaptação e Meio Ambiente*. 5th ed. Santos Editora, São Paulo.

Shivik, J.A., Wright, G.W. & Clark, L. (2000) Seasonal variability in brown tree snake *Boiga irregularis* responses to lures. *Can. J. Zool.*, 78, 79-84.

Sun, L., Shine, R., Debi, Z. & Zhengren, T. (2001) Biotic and abiotic influences on activity patterns of insular pit-vipers (*Gloydius shedaoensis*, Viperidae) from north-eastern China. *Biol. Conserv.*, 97, 387-398.

Vitt, L.J. (1995) The ecology of tropical lizards in the caatinga of Northeast Brazil. *Occas. Pap. Okla. Mus. Nat. His.*, 1, 1-25.

Vitt, L.J., Van Loben Sels, R.C. & Ohmart, R.D. (1981) Ecological relationships among arboreal desert lizards. *Ecology*, 62, 398-410.

Vitt, L.J. & Vangilder, L.D. (1983) Ecology of a snake community in northeastern Brazil. *Amphibia-Reptilia*, 4, 273-296.

Ward, D. & Lubin, Y. (1993) Habitat selection and the life history of a desert spider, *Stegodyphus lineatus* (Eresidae). *J. Anim. Ecol.*, 62, 353-363.

Willson, J. D. & Dorcas, M.E. (2004) Aspects of the ecology of small fossorial snakes in the western Piedmont of North Carolina. *Southeastern Naturalist*, 3, 1-12.

Winne, C.T., Dorcas, M.E. & Poppy, S.M. (2005). Population structure, body size, and seasonal activity of Black Swamp Snakes (*Seminatrix pygaea*). *Southeastern Naturalist*, 4, 1-14.

Copyright of Animal Biology is the property of Brill Academic Publishers and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.