Head triangulation as anti-predatory mechanism in snakes

Denise Dalbosco Dell'Aglio[1,3], Tiago Shizen Pacheco Toma[1], Adriane Esquivel Muelbert[1], Anne Gomes Sacco[1] & Alexandro Marques Tozetti[2]

[1]Programa de Pós-graduação em Ecologia, Instituto de Biociências, Universidade Federal do Rio Grande do Sul – UFRGS, Av. Bento Gonçalves, 9500, CEP 91501-970, Porto Alegre, RS, Brazil
[2]Universidade do Vale do Rio dos Sinos – UNISINOS, Av. Unisinos, 950, CEP 93022-000, São Leopoldo, RS, Brazil
[3]Corresponding author: Denise Dalbosco Dell'Aglio, e-mail: denise_ddd@hotmail.com

DELL'AGLIO, D.D., TOMA, T.S.P., MUELBERT, A.E., SACCO, A.G. & TOZETTI, A.M. **Head triangulation as anti-predatory mechanism in snakes**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?short-communication+bn01912032012

Abstract: Anti-predator mechanisms in snakes are diverse and complex, including mimetic behavior. Some snakes triangulate their head, probably mimicking other more dangerous snakes. However, there is a lack of studies that demonstrate the effectiveness of this behavior with natural predators. The aim of this study was to verify, using artificial snakes, if snakes with triangular heads are less susceptible to attack by predators, and if predatory attack is targeted to the head of serpents. Artificial snakes were systematically arranged on a road border. The rate of attacked models was 48.71%. Number of attacks on models with rounded head was significantly higher than in models with triangular head. There was a significant difference between the places of attack on the snakes in relation to different head shapes. Therefore, snakes that have head triangulation may be a less frequent target of attacks by predators than those without such behavior.
Keywords: *artificial models, defensive behavior, mimicry, predation rate, reptiles.*

DELL'AGLIO, D.D., TOMA, T.S.P., MUELBERT, A.E., SACCO, A.G. & TOZETTI, A.M. **Triangulação da cabeça como mecanismo anti-predação em serpentes**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?short-communication+bn01912032012

Resumo: Mecanismos anti-predação em serpentes são diversos e complexos, incluindo comportamentos miméticos. Algumas serpentes triangulam a cabeça, possivelmente mimetizando outras serpentes mais perigosas. No entanto, são escassos os estudos demonstrando a eficiência deste comportamento frente a predadores naturais. O objetivo deste estudo foi verificar, utilizando serpentes artificiais, se os indivíduos com cabeça triangular são menos suscetíveis ao ataque de predadores e, se o ataque predatório é direcionado à cabeça das serpentes. Serpentes artificiais foram dispostas sistematicamente na margem de uma estrada. A taxa de modelos atacados foi 48,71%. O número de ataques em modelos de cabeça arredondada foi significativamente maior do que nos modelos com cabeça triangular. Houve diferença significativa entre as partes atacadas nas serpentes quando comparados aos diferentes formatos de cabeça. Portanto, as serpentes que possuem triangulação da cabeça podem ser um alvo menos frequente de ataques por predadores do que as que não possuem esse tipo de comportamento.
Palavras-chave: *modelos artificiais, comportamento defensivo, mimetismo, taxa de predação, répteis.*

Introduction

Species' ability to defend themselves from a predator is intrinsically associated to their survival, increasing ability to explore the environment as well as to obtain resources (Lima & Dill 1990, Downes 2001). Reptiles exhibit extremely diverse anti-predator mechanisms, including cryptic coloration and behavior, mimicry, aposematism and also several ways to intimidate attackers (Pough et al. 2004). Many of these anti-predator mechanisms are assumed to be a visual intimidation for predators (Tozetti et al. 2009). Snakes are interesting models for defense mechanisms studies because besides having developed defensive behaviors, they are potential prey for many animals such as mammals, birds, other reptiles and invertebrates (Greene 1988).

Capacity of head triangulation is one of many tactics of defense. This ability can be observed in some species of *Dipsas*, which associated with coloration make them mimetic of *Bothrops jararaca*, a Viperidae snake widely distributed in Brazil (Tozetti et al. 2009). The mimetic behaviors displayed by these snakes, head triangulation and threatening posture, are known for many species of Colubrid snakes (Marques et al. 2001a), however, there are controversial data in studies showing their effectiveness against natural predators (Guimarães & Sawaya 2012, Valkonen & Mappes 2012).

Artificial models have been used in several studies as a tool to test anti-predation responses, for example fishes (Kelley & Magurran 2003), amphibians (Saporito et al. 2007), birds (Gottfried 1979, Gottfried et al. 1985), lizards (Leal & Rodriguez-Robles 1997), mammals (Barros et al. 2002, Vignieri et al. 2010) and particularly snakes (Brodie & Janzen 1995, Wilgers & Horne 2007, Niskanen & Mappes 2005, Guimarães & Sawaya 2011). Thus, using artificial snakes for studies with mimetic behavior and natural enemies' response seems to be an interesting, valid and effective method.

Therefore, the aim of this study was to verify, through an experiment using artificial snakes, if snakes with triangular head are less susceptible to attack by predators, and if predatory attack is targeted at the snake's head. Guimarães & Sawaya (2011) conducted a similar experiment which had negative results related to the effectiveness of having a triangular head. However, these results were contested by Valkonen & Mappes (2012). Our hypotheses are: (1) snakes with triangular head suffer less predation pressure; (2) as the snake's head is an important target, the head has higher attack rate (Langkilde et al. 2004, Niskanen & Mappes 2005); and (3) snakes with triangular head, supposedly to intimidate visual predators (Tozetti et al. 2009), suffer higher attack rate on the head than on other parts of the body, setting up more accurate attacks.

Materials and Methods

This study was performed at Research and Nature Conservation Center Pró-Mata (CPCN Pró-Mata) located in Araucaria Plateau, at approximately 900 m elevation (29° 27' S and 50° 08' W), in Rio Grande do Sul State, Brazil. The experiment was conducted in an area characterized by a mosaic of grasslands and Araucaria forest in different successional stages.

The experiment was conducted on January 2011 and consisted of 80 artificial snake models made of non-toxic modeling plasticine, 40 triangular head and 40 round head. Artificial models measured about 20 cm long and 1 cm wide, grayish color (Figure 1a, b). The coloration and size was similar to the color pattern of species commonly found in the region (e.g. *Liophis poecilogyrus* or juveniles of *Philodryas patagoniensis*, Di-Bernardo 1998). Snake models were disposed on a margin of a country road every 20 m following a sequence of 10 round models and 10 triangular models. There were four sections of 400 m by 500 m apart to ensure both autonomy between samples and spatial homogeneity of the surrounding vegetation. The models were exposed for 17 hours, overnight, and collected the next morning. In field, each model was analyzed for attack presence, number of attacks, part of the model that suffered the attack (head or other parts of the body) and type of attack.

Data analysis was performed in the program Past (Hammer et al. 2001) using Chi-square test ($\alpha = 0.05$) to compare proportion of attacks on triangular and round head snakes models and proportion of attacks in the head and body between the two kinds of snake models.

Results

From the 80 snake models, one of each treatment was excluded from analysis because they were damaged by human activities. A total of 38 (48.71%) models were attacked. A significant higher number of attacks was deferred on round head models (25 attacks) than on triangular head models (13 attacks) ($\chi^2 = 14.40$, df = 1, $p < 0.001$).

The number of attacks differed significantly between the head (12 attacks) and other parts of the body (31 attacks) ($\chi^2 = 89.82$, df = 1, $p \leq 0.001$). Five models were attacked both in the head and other parts of the body. The difference between the part of the model attacked in relation to the shape of the head was significant ($\chi^2 = 12.64$, df = 1, $p \leq 0.001$, Figure 2).

The types of attacks suffered by the artificial snakes were pecking and scratching (Figures 1c-e). Some of the models were broken and lacerated, including some missing tails. However, it was not possible to identify the predators through the attack imprints.

Discussion

Approximately half of artificial snakes were attacked, showing effectiveness of this technique to test the hypotheses of this study. Artificial snakes were successfully used in other studies, for example Wilgers & Horne (2007) investigated predation of artificial snakes in burned environments, Brodie & Janzen (1995) observed avoidance by avian predators of bicolor ringed pattern in snakes and Guimarães & Sawaya (2011) also tested the predation of triangular head shape snakes.

The hypothesis that lower predation rates occur on snakes with triangular heads was corroborated. A different result was found by Guimarães & Sawaya (2011), in whose study the head shape seemed not to confer advantage. These differences between studies may result from the different ecosystems where they were conducted. Head triangulation behavior, recurrently shown in the literature (Tozetti et al. 2009, Marques et al. 2001a), seems to be an effective strategy that results in a higher survival rate. Lower predations rates are also shown in other mimetic systems. For example, mimics of the coral snake *Micrurus nigrocinctus* are often less attacked than non-mimics (Brodie 1993).

Contrary to our prediction, the snake head was not an important target, presenting lower attack rates than other parts of the body in both types of models. Rodrigues (2005) reports predator preference for attacking the snake tails, however this was not evaluated in this study. Although attacks frequency was greater in other parts of the body than head, our experiment may have favored opportunistic animals, which may not tactically attack the head (Brodie 1993, Buasso et al. 2006). At our study site, there are records of several snakes' potential predators, including large and medium-size mammals, such as ocelots (*Leopardus pardalis*), wild cats (*Leopardus tigrinus*) and crab-eating foxes (*Cerdocyon thous*), small mammals (Marques et al. 2001b) and birds of prey (Fontana et al. 2008). Since it was not possible to identify the predators through the marks left, future work using camera traps would be useful to identify if predatory attack being directed to the snake's head is related to a specific type of predator.

Figure 1. Artificial snake models in field: a) round head, b) triangular head. Examples of attacks: c) scratches in the head, d) scratches in other part of the body, e) pecking in the head.

Figura 1. Modelos artificiais de serpente em campo: a) cabeça arredondada, b) cabeça triangular. Exemplos de ataques: c) arranhões na cabeça, d) arranhões no corpo, e) bicadas na cabeça.

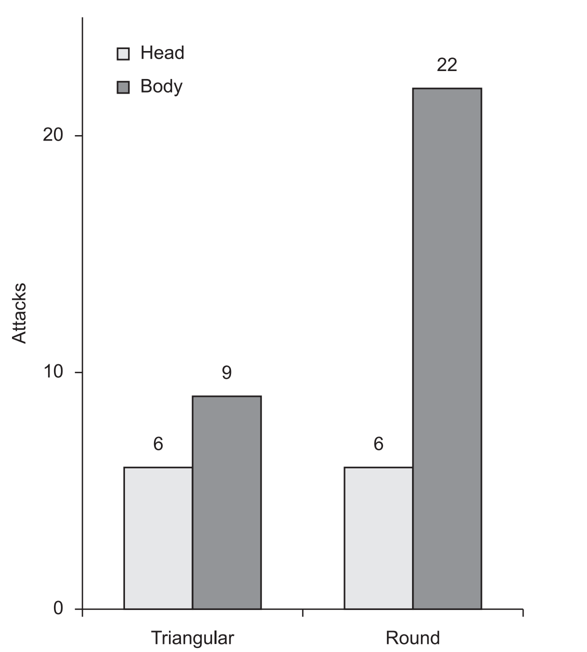

Figure 2. Number of artificial snake models attacked of triangular and round head divided in head and other parts of the body ($p \leq 0.001$).

Figura 2. Número de modelos artificiais de serpentes atacadas de cabeça triangular e arredondada divididos em cabeça e corpo ($p \leq 0.001$).

The use of plasticine models was in general effective to test our hypotheses, but results may be interpreted with caution to avoid eventual bias. First, the use of artificial snake models may have favored diurnal predators, which locate their prey visually, as opposed to nocturnal predators, which use their olfactory system to locate prey. Moreover, the fact that artificial models are static may contribute to high incidences of attacks since there was no defensive behavior to inhibit them. Also aerial predators identify their prey visually by motion, so stationary artificial snakes would decrease detection by these predators (Wilgers & Horne 2007), reducing the effect of such bias.

Despite of the importance of a set of defensive mechanisms or behaviors (Guimarães & Sawaya 2011), triangular shape of the head seems to be useful to prevent predation. Our data showed that snakes with triangular head are less frequent targets than the ones with round head. Then, such mimic behavior could avoid predator attacks. The results of this study using artificial snake models are expected to be used as basis for future studies about predator-prey interactions.

Acknowledgements

André Victor Lucci Freitas and Fernando Gertum Becker for early suggestions to the manuscript. Two anonymous reviewers made valuable suggestions on the manuscript. PPG-Ecologia UFRGS for funding the field work. CPCN Pró-Mata for providing permission to access the study site. This work was developed during the 2011 Ecology Field Course by PPG-Ecologia UFRGS.

References

BARROS, M., BOERE, V., MELLO, L.E. & TOMAZ, C. 2002. Reactions to potential predators in captive born marmosets (*Callithrix penicillata*). Int. J. Primatol. 23:443-454. http://dx.doi.org/10.1023/A:1013899931878

BRODIE, E.D. 1993. Differential avoidance of coral snake banded patterns by free-ranging avian predators in Costa Rica. Evolution 47:227-235.

BRODIE, E.D. & JANZEN, F.J. 1995. Experimental studies of Coral Snake mimicry: generalized avoidance of ringed snake patterns by free-ranging avian predator. Funct. Ecol. 9:186-190.

BUASSO, C.M., LEYNAUD, G.C. & CRUZ, F.B. 2006. Predation on snakes of Argentina: effects of coloration and ring pattern on coral and false coral snakes. Stud. Neotrop. Fauna E. 4:183-188. http://dx.doi.org/10.1080/01650520600630725

DI-BERNARDO, M. 1998. História natural de uma comunidade de serpentes da Borda Oriental do Planalto das Araucárias, Rio Grande do Sul, Brasil. Tese de Doutorado, Universidade Estadual de São Paulo, Campus Rio Claro, São Paulo.

DOWNES, S. 2001.Trading heat and food for safety: costs of predator avoidance in a lizard. Ecology 82:2870-2881.

FONTANA, C.S., ROVEDDER, C.E., REPENNING, M., GONÇALVES, M.L. 2008. Current state of knowledge and conservation of the avifauna from Campos de Cima da Serra highlands of South Brazil, Rio Grande do Sul and Santa Catarina States. Rev. Bras. Ornitol. 16(4):281-307.

GOTTFRIED, B.M. 1979. Antipredator aggression in birds nesting in old field habitats: an experimental analysis. Condor 81:251-252.

GOTTFRIED, B.M., ANDREWS, K. & HAUG, M. 1985. Breeding robins and nest predators: effect of predator type and defense strategy on initial vocalization patterns. Wilson Bull. 97:183-190.

GREENE, H.W. 1988. Antipredator mechanisms in reptiles. In Biology of the reptilian (C. Gans & R.B. Huey, eds). Alan R. Liss, New York, p.1-152.

GUIMARÃES, M. & SAWAYA, R.J. 2011. Pretending to be venomous: is a snake's head shape a trustworthy signal to a predator? J. Trop. Ecol. 27:437-439. http://dx.doi.org/10.1017/S0266467411000095

GUIMARÃES, M. & SAWAYA, R.J. 2012. The snake head-shape signal: a reply to Valkonen & Mappes. J. Trop. Ecol. 28:125-126. http://dx.doi.org/10.1017/S0266467411000587

HAMMER, O., HARPER, D.A.T., & RYAN, P.D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontol. Electron. 4(1):9.

KELLEY, J.L. & MAGURRAN, A.E. 2003. Effects of relaxed predation pressure on visual predator recognition in the guppy. Behav. Ecol. Sociobiol. 54:225-232. http://dx.doi.org/10.1007/s00265-003-0621-4

LANGKILDE, T., SHINE, R. & MASON, R.T. 2004. Predatory attacks to the head vs. body modify behavioral responses of garter snakes. Ethology 110:937-947. http://dx.doi.org/10.1111/j.1439-0310.2004.01034.x

LEAL, M. & RODRIGUEZ-ROBLES, J.A. 1997. Signalling displays during predator-prey interactions in a Puerto Rico anole, *Anolis cristatellus*. Anim. Behav. 54:1147-1154. PMid:9398368.

LIMA, S.L. & DILL, L.M. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Can. J. Zoolog. 68:619-640.

MARQUES, O.A.V., ETEROVIC, A. & SAZIMA I. 2001a. Serpentes da Mata Atlântica. Guia ilustrado para a Serra do Mar. Editora Holos, Ribeirão Preto, Brazil.

MARQUES, R.V., CADEMARTORI, C.V. & PACHECO, S.M. 2001b. Mastofauna no Planalto das Araucárias, Rio Grande do Sul, Brasil. Rev. Bras. Bioci. 9(3):278-288.

NISKANEN, M. & MAPPES, J. 2005. Significance of the dorsal zigzag pattern of *Vipera latastei gaditana* against avian predators. J. Anim. Ecol. 74:1091-1101. http://dx.doi.org/10.1111/j.1365-2656.2005.01008.x

POUGH, F.H., ANDREWS, R.M., CADLE, J.E., CRUMP, M.L., SAVITSKY, A.H. & WELLS, K.D. 2004. Herpetology. Pearson Prentice Hall, Upper Saddle River, New Jersey.

RODRIGUES, M.G. 2005. A triangulação da cabeça diminui a chance de predação em serpentes? In Curso de Ecologia da Floresta Amazônica (Instituto Nacional de Pesquisas da Amazônia - INPA). INPA. http://pdbff.inpa.gov.br/.

SAPORITO, R.A., ZUERCHER, R., ROBERTS, M., GEROW, K.G. & DONNELLY, M.A. 2007. Experimental evidence for aposematism in the Dendrobatid poison frog *Oophaga pumilio*. Copeia 2007(4):1006-1011. http://dx.doi.org/10.1643/0045-8511(2007)7[1006:EEFAIT]2.0.CO;2

TOZETTI, A.M., OLIVEIRA, R.B. & PONTES, G.M.F. 2009 Defensive repertoire of *Xenodon dorbignyi* (Serpentes, Dipsadidae). Biota Neotrop. 9(3): http://www.biotaneotropica.org.br/v9n3/en/abstract?article+bn03409032009 (último acesso em 16/06/2011).

VIGNIERI, S.N., LARSON, J.G. & HOEKSTRA, H.E. 2010. The selective advantage of crypsis in mice. Evolution 64(7):2153-2158. http://dx.doi.org/10.1111/j.1558-5646.2010.00976.x

VALKONEN, J.K. & MAPPES, J. 2012. Comments on Guimarães & Sawaya. Pretending to be venomous: is a snake's head shape a trustworthy signal to a predator? J. Trop. Ecol. 28:123-124. http://dx.doi.org/10.1017/S0266467411000575

WILGERS, D.J. & HORNE, E.A. 2007. Spatial variation in predation attempts on artificial snakes in a fire-disturbed tallgrass prairie. Southwest. Nat. 52(2):263-270.

Received 30/11/2011
Revised 28/07/2012
Accepted 13/08/2012