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CONSERVATION OF THE CAECILIAN *Siphonops annulatus* (AMPHIBIA, GYMNOPHIONA) IN BRAZILIAN CACAO PLANTATIONS: A SUCCESSFUL RELATIONSHIP BETWEEN A FOSSORIAL ANIMAL AND AN AGROSYSTEM

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Cacao plantations give an important contribution to the conservation of the Atlantic Forest biome, considered the most threatened biodiversity hotspot in South America. Due to their mainly fossorial way of life, caecilian amphibians are the least known order of terrestrial vertebrates. We present observations on the Neotropical siphonopid caecilian *Siphonops annulatus* (Mikan 1820), which is abundant in the cacao plantations of Southern Bahia. "Cabruca" is the most traditional form of cacao cultivation in this region and uses large native trees which create a fresh, shady environment with an nutrient rich, humid, leaf litter that is highly suitable for caecilians. The current abundance and easiness of observation of *S. annulatus* makes this region particularly favourable to long-term studies of the ecology of this caecilian. Local knowledge associates the occurrence of these animals with well-established and fertile cacao plantations. The preservation of *S. annulatus* in this region seems intrinsically linked to the maintenance of the cabruca. Our concern is that the possible regional reduction of cacao cultivation would lead to the loss of one of the most important open laboratories in the world in which caecilians can be studied in nature.

Key words: Neotropical Region, Siphonopid caecilian, agroforestry, cabruca, *Theobroma cacao*, Brazilian Atlantic Forest

Conservação da cobra-cega *Siphonops annulatus* (Amphibia, Gymnophiona) em cacauais do Brasil: uma relação bem sucedida entre um animal fossório e um agrossistema. Os cacauais contribuem sobremaneira para a conservação do bioma Mata Atlântica, que é considerado o "hotspot" de biodiversidade mais ameaçado da América do Sul. Devido ao seu modo de vida principalmente fossorial, os anfíbios cobras-cegas (também conhecidos como cecílias) representam a ordem menos conhecida de vertebrados terrestres. Apresentamos observações sobre a espécie neotropical *Siphonops annulatus* (Mikan 1820) que é particularmente abundante nas plantações de cacau do sul da Bahia. A "cabruca" é a mais tradicional forma de cultivo de cacau na região, utilizando grandes árvores nativas para criar um ambiente fresco, sombreado com uma serapilheira úmida e rica em matéria orgânica, ideal para manutenção das cobras-cegas. A abundância e a facilidade de observação do *S. annulatus* fazem com que esta região seja particularmente favorável aos estudos ecológicos de longo prazo sobre essa espécie. A cultura tradicional dos moradores da região cacaueira associa a ocorrência desses animais com plantações bem estabelecidas e férteis. Assim, a preservação da população local de *S. annulatus* parece intrinsecamente ligada à manutenção da cabruca. Nossa preocupação é que uma possível redução da atividade econômica do cacau ao nível regional possa levar à perda de um dos mais importantes laboratórios abertos do mundo que permite o estudo das cobras-cegas na natureza.

Palavras-chave: Região Neotropical, cecília, agrofloresta, cabruca, *Theobroma cacao,* Mata Atlântica

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Introduction

Cacao plantations (*Theobroma cacao* L., Malvaceae) have made an important contribution to the conservation of the Brazilian Atlantic Forest biome (Schroth et al., 2011), considered the most threatened biodiversity hotspot in South America (Myers et al., 2000). One type of plantation, known as "cabruca", is an agroforestry system where cacao trees are planted in the shadow of selected large native trees after elimination of the undergrowth (Cassano et al., 2009; Landau et al., 2008). Besides preserving biodiversity, the cabruca also preserves many of the original soil characteristics of the Atlantic Forest (Johns, 1999). The area occupied by cacao plantations has been the subject of many studies aimed at enhancing knowledge of the great diversity of species (many of them endemic) found within, and of the viability of their populations (Cassano et al., 2009; Pardini et al., 2009; Delabie et al., 2011).

Due to their mainly tropical distribution and primarily fossorial way of life, caecilian amphibians (Gymnophiona) are the least known order of terrestrial vertebrates (Jared et al., 1999). Their subterranean lifestyle limits opportunities for direct observation without disturbance of the animal and its environment that do not facilitate any kind of study. Hence, information concerning many aspects of caecilian biology, especially ecology and behaviour, is scarce. These superficially worm- or snake-like amphibians, many species of which are known only from type specimens, lack limbs and girdles and the little more than 200 described species (c. 3% of all amphibians) (Frost, 2015), are divided into ten families, each an ancient lineage that, according to molecular timetrees, originated in the mesozoic (Wilkinson et al., 2011; Kamei et al., 2012).

Little information exists on geographic distribution, natural history and ecology of Brazilian caecilians and salamanders (Silvano & Segalla, 2004). According to the Sociedade Brasileira de Herpetologia (2014), Brazil has 33 described species of caecilian, which represents about 16% of the global diversity. The fossorial caecilian *Siphonops annulatus* Mikan 1820, popularly known as "cobra-cega" (blind snake) or "cobra-preta" (black snake), (Figure 1) is the best known member of the Neotropical family Siphonopidae (5 genera, 26 species) and has the broadest distribution of any caecilian, both geographically (reported or expected from every South American country except Chile), and ecologically, being reported from environments as different as rainforests and semiarid regions (Taylor, 1968).

Since 1988, frequent expeditions to Southern Bahia, Brazil, were made aiming to study the herpetofauna of the region and its relationship with the cacao plantations, specially focusing on fossorial species, with a range of observations on caecilians. With the knowledge acquired from field observations in Southern Bahia, a methodology for maintaining and breeding *S. annulatus* in captivity was established and this animal has been shown to be a good model for the study of caecilians (Junqueira et al., 1999; Jared et al., 1999). Unfortunately, along with other vertebrates of the Atlantic Rainforest, it has been facing habitat loss and reduction of populations for five centuries of deforestation. Presently, only about 7% remains of the original extent of the Atlantic Rainforest (Myers et al., 2000; Becker et al., 2007). We present hereafter a synthesis of all our observations on *S. annulatus* in cacao plantations where most of our observations on the caecilian in its natural habitat were made. The cabruca seems providing a propitious environment for maintenance and preservation of still large populations of this caecilian and constitutes a natural laboratory for the study of a caecilian species in the wild.

Materials and Methods

S. annulatus (Figure 1) was observed in the soil of cacao farms and Atlantic Rainforest remnants all in the two neighbour municipalities of Ilhéus and Itabuna. Located in the cacao producing region of the state of Bahia, Brazil, these municipalities are situated approximately between 39º00' and 39º30'W, and 14º20' and 15º00'S and Ilhéus is bordered to the east by the Atlantic Ocean (Faria Filho e Araujo, 2003). The climate is typically humid or sub humid with average annual temperatures from 21º to 25ºC, maxima between 26.1ºC and 30.3ºC, minima from 17.1ºC to 20.8ºC and daily variation of no more than 10ºC (Santana et al., 2003). The precipitations are regular with abundant rains throughout the year particularly during summer and winter, and, close to the coast, an annual rainfall of 2,700 mm (Faria Filho e Araujo, 2003).

Figure 1. Aspect of an adult *Siphonops annulatus* in the leaf litter of the cacao plantation immediately after having been disinterred from the soil.

The original vegetation of the region was perennial, broad-leaved, closed, moist forest, typical from the Atlantic Rainforest biome. It was a dense, shady forest characterized by an abundance of large trees and epiphytes with a great variety of lianas, ferns, and palms (Velloso et al., 1991). The regional traditional cultivation of the cacao tree beneath the forest canopy began as long as 250 years ago (Campos, 1981) and was developed as the cabruca system, with cacao planted beneath large native trees (Schroth et al., 2011) and forming a type of sub forest protected from direct sunlight (Figure 2a). The umbrella of the original forest canopy reproduces the ideal conditions of fructification of the cacao tree (Figure 2b) in the warm and humid shade with a soil permanently covered by a thick layer of litter laid on fertile soils (Figure 2c).

Figure 2. *Siphonops annulatus* habitat: cacao plantation. (a) View from outside showing the forest-like canopy created by shade trees. (b) Cacao pods ripening within the plantation. (c)Plantation interior view showing understory and thick leaf litter.

The harvest period of cacao is especially interesting for cecilian observations and for that reason we focus on it. There are at least ten pod harvests in a cacao area per year, due to the long period of flowering of the trees (>9 months) (Dias, 2001). Soon after the harvest, while still inside the plantation, the pods are broken and the seeds removed. The emptied pods are discharged in piles accumulated in mounds in the plantation itself, regionally known as “casqueiros” (Figure 3a), where they rapidly decompose.

The data presented here were obtained in several expeditions (twice a year, generally), between 1988 and 2009, in January and February (Austral summer) and July and August (Austral winter). During our expeditions, adult and young specimens were collected using shovels to dig the soil, turning falling vegetation or revolving other sites rich in organic matter.

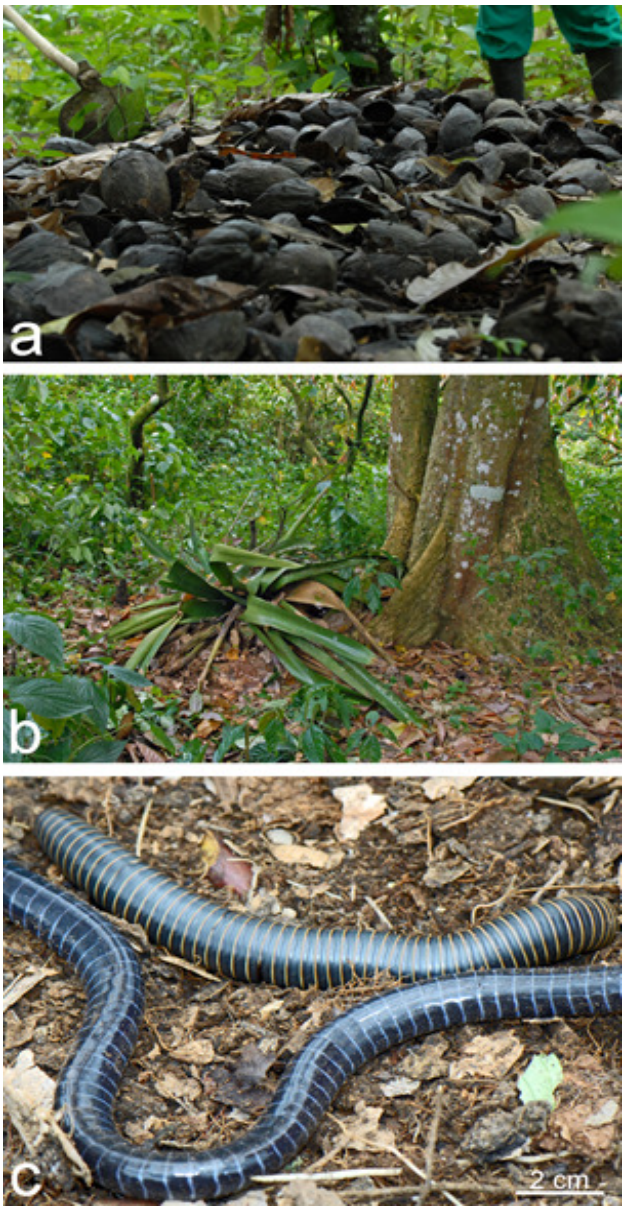

Figure 3. Favorable habitats where *Siphonops annulatus* are found. (a) "Casqueiro", a pile of decomposing cacao pods. (b) A fallen epiphytic bromeliad, common in the cacao plantations, under which a generous amount of decomposing organic material is formed. (c) Possible mimicry between *Siphonops annulatus* (below) and the Diploda *Rhinocricus* sp. (above) in the cacao plantations.

Results

From all animals collected, 41 specimens obtained from cabrucas of southern Bahia were measured aiming to obtain their average weight [64.4 g ± 3.0 (SE)] and length [37.1 cm ± 0.1 (SE)].

The organically rich "casqueiros" provide suitable shelter for mainly invertebrates, but also small mammals, reptiles and amphibians, such as *Siphonops annulatus*. Additionally, *S. annulatus* can be found near the roots of the large shade trees such as eritrina (*Erythrina* spp.) and gameleira (*Ficus subtriplinervia* Mart.), which also provide an extremely humid and nutrient rich environment of accumulated humus. Another place preferred by *S. annulatus* is beneath large epiphytic bromeliads, mainly *Aechmea lingulata* L. that, having grown too heavy to be supported by their host tree's branches, have fallen to the ground. The microhabitat generated below the fallen bromeliad (Figure 3b) is rich in decomposing organic material and has a diverse and abundant fauna of invertebrates and, along with *S. annulatus*, the amphisbaenian *Leposternon infraorbitale* Berthold 1859 and the snake *Typhlops brongersmianus* Vanzolini 1972 are common.

During July and August when there are prolonged and heavy rains, it is possible to find *S. annulatus* and *Leposternum infraorbitale* crawling on the surface. Rarely, we have also seen *S. annulatus* swimming maintaining its head above the surface in the canals that run through the cacao plantations. We have never found this caecilian in very sandy or rocky grounds. Although found most commonly in sheltered old cacao plantations, they can also sometimes be found in the unsheltered edges of the plantations and adjacent grassland. *Siphonops annulatus* can also be found under piles of cut grass in the fields.

In nature, *S. annulatus* constructs permanent tunnel systems that are sometimes visible during excavations and are characterized by smooth and shiny walls. The shine is presumably the result of the abundant cutaneous secretions that are mainly noticed when the animal is manipulated. These secretions can cause irritation to humans if it makes contact with any open cuts, abrasions or mucous membranes. In addition, their smell may induce sneezing in some individuals. Nonetheless, *S. annulatus* are generally inoffensive, very rarely bite and mostly can be handled with impunity either in the field or in the laboratory.

S. annulatus and the millipede *Rhinocricus* sp. (Diplopoda, Spirobolida, Rhinocricidae), known locally as "gongo", are syntopic and, inside the cacao plantation, share the same microhabitats. They are easily found in casqueiros or other sites rich in organic

matter. Both animals are similar in dimensions, colour and have the body marked by numerous whitish annuli. Hence, during excavations for collecting, they are easily confused with one another (Figure 3c).

Discussion

The cabruca is a form of cacao cultivation that is considered very favourable to the preservation of the environment (Schroth et al., 2011) and there is a widespread idea among the people from the cacao region of southern Bahia that the cacao plantations and the forest cannot be separated. The leaves continuously falling on the ground inside the plantation are never removed keeping the soil permanently wet. With decomposition, a thick protective layer is formed covering the ground and limiting the evaporation of rainfall. This environment, rich in organic matter, is structurally similar to that of the original Atlantic Rainforest (Johns, 1999; Schroth et al., 2013) presumably the natural habitat of *S. annulatus*, and seems well suited to supporting the continued existence of this caecilian. In some plantations, it seems that the leaf litter formed from cacao trees is more substantial, continuous and thicker than in some forest areas. Thus, among animals, a range of fossorial species can have taken advantage of the transformation of the original forest into cabruca.

Perhaps more so than in many other areas in which it occurs, *S. annulatus* are especially popularly well known in southern Bahia. Although they ignore the biological and systematic characteristics of caecilians, many people living in the rural zone can cite, with considerable precision, the habits of "cobra-preta", as *S. annulatus* is known in the region. Commonly, we have found that farm workers associate the occurrence of these animals with humid grounds, rich in organic matter, such that they are popularly associated with soil fertility and considered to be indicative of well-established and productive cacao plantations. Unfortunately there are no data on population density of *S. annulatus* or of the effect of these animals on the fertility of cacao plantation soils, but this relationship certainly deserves further research.

Despite the intensity of human intervention in the Atlantic Rainforest, cacao plantations seem to provide an excellent sanctuary for *S. annulatus* and the future survival of this species in southern Bahia may be heavily dependent on the persistence of this kind of agriculture, which, however, seems increasingly uncertain due to the low productivity and profitability of cacao production in this traditional system, especially since the introduction and spread of the pathogenic basidiomycete fungus *Moniliophthora perniciosa*, the agent of the ''witches' broom'' disease, in the 1980's. We note that cacao plantations also provide seemingly good environments for a variety of other caecilians in other places also. For example, the dermophiid *Schistometopum thomense* and the indotyphlid *Hypogeophis rostratus* are abundant in cacao plantations in Sao Tomé and Principe (Africa) and the Seychelles Islands (Indian Ocean) respectively (R. A. Nussbaum pers. comm.). Interestingly, we have observed a species of the siphonopid genus *Microcaecilia* to be common in cupuaçu plantations (*Theobroma grandiflorum* (Willd. ex Spreng.) K. Schum., Malvaceae), in the southwest of the Brazilian state of Pará (Wilkinson et al., 2015).

Despite the present concern about global amphibian declines (Young et al., 2004), caecilians are rarely included in faunal surveys contributing to the general lack of knowledge of their biology (Jared et al., 1999) and of their distributions and abundance (Gower &Wilkinson, 2005) that hinders the establishment of a conservation strategy for them. Globally the amphibian diversity decline is due to habitat destruction, mainly through vegetation devastation and pollution (Pillai & Ravichandran, 1999) and urbanization (Maneyro & Langone, 2001). However the lack of systematic inventories prevents any conclusions of a speculative but possible caecilian decline. We notice yet that current abundance and ease of capture of *S. annulatus* makes south of Bahia a well-suited region to long-term study of the ecology of this caecilian, including its role in the agricultural environment. We fear that transformation of cabruca into other types of cacao plantations, pastures or any other form of agriculture that does not preserve forest-like canopy, soils and shaded dense leaf litter, is the greatest threat to this species in particular and to the amphibian fauna more generally.

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Literature Cited

BECKER, C. G., et al. 2007. Habitat split and the global decline of amphibians. Science 318:1775-1777.

CAMPOS, S. 1981. Crônicas da Capitania de São Jorge dos Ilhéus (Primeira Edição: 1936). Rio de Janeiro, RJ, Conselho Federal de Cultura. 536p.

CASSANO, C. R., et al. 2009. Landscape and farm scale management to enhance biodiversity conservation in the cocoa producing region of southern Bahia, Brazil. Biodiversity and Conservation 18:577-603.

DELABIE, J. H. C., et al. 2011. Paisagem cacaueira no sudeste da Bahia: desafios e oportunidades para a conservação da diversidade animal no Século XXI. Agrotrópica (Brasil) 23: 107-114.

DIAS, L.A.S. 2001. Melhoramento genético do cacaueiro. Viçosa, MG, Editora Funape. 578p.

FARIA FILHO, A. F.; ARAUJO, Q. R. 2003. Zoneamento do meio físico do Município de Ilhéus, Bahia, Brasil, utilizando a técnica de geoprocessamento. Ilhéus, BA, CEPLAC/ CEPEC. Boletim Técnico nº 187.

FROST, D. R. 2014. Amphibian Species of the World: an online reference. Version 6.0 (02/27/2015). Electronic Database accessible at http://research.amnh.org/herpetology/amphibia/ index.html. New York, American Museum of Natural History.

GOWER, D. J.; WILKINSON, M. 2005. Conservation biology of caecilian amphibians. Conservation Biology 19: 45-55.

HIMSTEDT, W. 1996. Die Blindwühlen. Westarp Wissenschaften, Magdeburg. 160p.

JARED, C., NAVAS, C. A.; TOLEDO, R. C. 1999. An appreciation of the physiology and morphology and physiology of caecilians (Amphibia: Gymnophiona). Comparative Biochemistry and Physiology 123:313-328.

JOHNS, N.D. 1999. Conservation in Brazil's chocolate forest: the unlike persistence of the traditional cacao agroecosystem. Environmental Management 23:31-47.

JUNQUEIRA, L. C. U., JARED, C.; ANTONIAZZI, M. M. 1999. Structure of the caecilian *Siphonops annulatus* (Amphibia, Gymnophiona): general aspect of the body, disposition of the organs and structure of the mouth, oesophagus and stomach. Acta Zoologica Fennica 80:75-84.

KAMEI, R. G., et al. 2012. Discovery of a new family of amphibians from northeast India with ancient links to Africa. Proceedings of the Royal Society B., 279:2396-2401.

LANDAU, E. C., HIRSCH, A.; MUSINSKY, J. 2008. Vegetation cover and land use in the Atlantic forest of southern Bahia, Brazil, based on satellite imagery: a comparison among municipalities. In: Thomas,W.W.; Britton,E.G., eds.The Atlantic Coastal Forest of the Northeastern Brazil. New York, The New York Botanical Garden Press. pp. 221-244.

MANEYRO, R.; LANGONE J. A. 2001. Categorización de los anfibios del Uruguay. Cuadernos de Herpetología 15:107-118.

MYERS, N., et al. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858.

PARDINI, R., et al. 2009. The challenge of maintaining Atlantic forest biodiversity: A multi-taxa conservation assessment of specialist and generalist species in an agro-forestry mosaic in southern Bahia. Biological Conservation 142:1178-1190.

PILLAI, R. S.; RAVICHANDRAN, M. S. 1999. Gymnophiona (Amphibia) of India. A taxonomic study. Records Zoological Survey India Occasional Papers 72:1-117.

SANTANA, S. O., et al. 2003. Zoneamento agroecológico do Município de Ilhéus, Bahia, Brasil. Ilhéus, BA, CEPLAC/ CEPEC. Boletim Técnico nº 186.

SCHROTH, G., et al. 2011. Conservation in tropical landscape mosaics: the case of the cacao landscape of southern Bahia, Brazil. Biodiversity and Conservation 20:1335-1354.

SCHROTH, G., et al. 2013. Contribution of agroforestry to landscape carbon storage. Mitigation and Adaptation Strategies for Global Change 20:1175-1190.

SILVANO, D. L.; SEGALLA, M. V. 2004. Conservation of Brazilian amphibians. Conservation Biology 19: 653–658.

SOCIEDADE BRASILEIRA DE HERPETOLOGIA. 2014. List of amphibians of Brazil. http://www.sbherpetologia.org.br/ index.php/anfibios. Accessed 02/27/2015.

TAYLOR, E. H. 1968. The caecilians of the world. A taxonomic review. Lawrence, University of Kansas Press.

VELLOSO, H. P., RANGEL FILHO, A. L. R.; LIMA, J. C. A. 1991. Classificação da vegetação brasileira adaptada a um Sistema Universal. Rio de Janeiro, RJ, IBGE. 124p.

WILKINSON, M., et al. 2011. A nine-family classification of caecilians (Amphibia: Gymnophiona). Zootaxa 2874:41-64.

WILKINSON, M.; ANTONIAZZI, M. M.; JARED, C. 2015. A new species of *Microcaecilia* Taylor, 1968 (Amphibia: Gymnophiona: Siphonopidae) from Amazonian Brazil. Zootaxa 3905:425-431.

YOUNG, B. E., et al. 2004. Disappearing Jewels: the Status of new world Amphibians. Arlington, Virginia, Nature Serve. 58p.

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