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BIOMETRY AND GEOGRAPHICAL DIFFERENTIATION OF *AMPHISBAENA ROBERTI* GANS, 1964 (REPTILIA, AMPHISBAENIA)

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ABSTRACT

Geographical differentiation of biometrical characters (scale counts and body proportions) of A. roberti was studied with basis on 52 specimens from 19 localities. Six meristic and 3 morphometric characters were studied. Number of body annuli, number of tail annuli and total number of annuli revealed the presence of statistically significant geographical differentiation; number of segments to a midbody annulus (dorsal, ventral and sum) did not. Tail length and head length also showed differentiation, while head width did not.

In no case was found any geographical or ecological common denominator to the patterns of geographical differentiation. On the contrary, a mosaic pattern seemed to prevail, indicating a high degree of genetic isolation among local populations.

INTRODUCTION

Amphisbaena roberti Gans, 1964, belongs to a group of South American species bearing a terminal vertical keel on the tail. The other species in the group are *A. steindachneri* Strauch, 1887, *A. borellii* Peracca, 1987, and *A. bahiana* Vanzolini, 1964.

A. roberti is known from Brasil, between the parallels of 9° and 24°S, from the coast to the right (eastern) bank of the Rio Araguaia, in Central Brasil.

In his original description Gans (1964: 411) comments on the presence of geographical differentiation in the new form; after some brief remarks on scale counts and relative tail length he proposes a scheme comprising "at least three populations: one in coastal to southern São Paulo, a second one in northeastern São Paulo, a third in Minas Gerais and Goiaz..." He also makes an intriguing remark on tail length (1964: 411): "The plot surprisingly suggests that the low annulus count São Paulo specimens have a significantly shorter tail than the high count São Paulo specimens. The available specimens from Minas Gerais and Goiaz have longer tails than either."

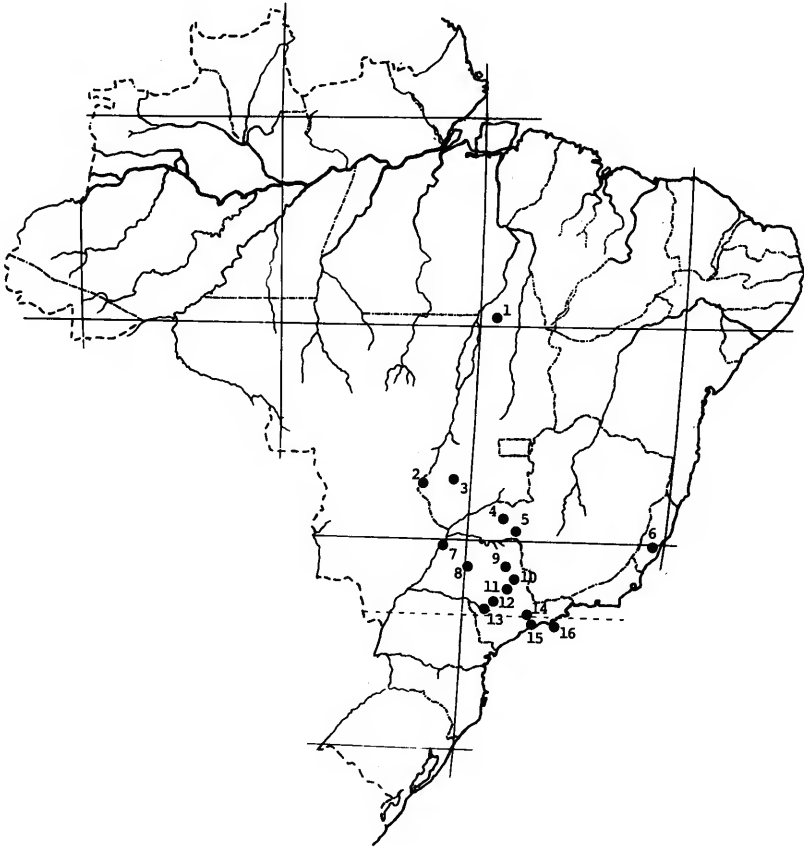
Gans's geography was incorrect, but the fact remains that the evidence of geographical differentiation in scale counts was unmistakable; that on tail length was less cogent, but nevertheless impressive.

Having reasonable materials at hand, I decided to probe into the geographical differentiation of *A. roberti*.

MATERIALS

I used (see Appendix) 52 specimens of *A. roberti* from our collection, representing 19 localities (Map 1).

There was not a single fully satisfactory homogeneous sample, with enough specimens and a broad enough range of body sizes to afford a good standard of local variation. There were, however, 5 usable samples, with from 5 to 9 individuals, with a good spread of body sizes. Three



Distribution of *Amphisbaena roberti*. 1, Piau. 2, Santa Rita do Araguaia. 3, Rio Verde. 4, Uberlândia. 5, Peirópolis. 6, Chaves. 7, Ilha Solteira. 8, Avanhandava. 9, Ribeirão Preto. 10, Emas. 11, Rio Claro; Leme. 12, Botucatu. 13, Avaré. 14, S. Paulo; Poá. 15, S. Vicente. 16, Ilha de São Sebastião.

of these samples could, additionally, be reinforced with specimens from neighboring localities with the same general ecology. They allowed a good first approximation.

I had the following "geographical" or "larger" samples.

1. Peirópolis, in the so-called "Triângulo Mineiro" (Minas Gerais Triangle, a sort of panhandle between S. Paulo and Goiás), a region originally covered with cerrados, now mostly under agriculture and pasture. This sample, with 9 specimens, was reinforced with two further examples from the neighboring (100 km to the northwest) locality of Uberlândia. In order to stress the composite nature of these samples I am calling them by the name of the main locality, followed by an asterisk; thus, "Peirópolis*".
2. S. Paulo, the state capital, where the species was apparently once abundant; 6 specimens, including one from the suburb of Poá (not "Pôa" as in Gans, 1964).
3. Emas*, in the outlying pocket of cerrado in the state of S. Paulo; 7 specimens reinforced with one from Rio Claro and one from Leme, both in the same general area, respectively at 60 and 35 km from Emas.
4. Botucatu*, in an area of open formations, mostly cerrado; 6 specimens, reinforced with one from Avaré, 50 km to the southwest.
5. Ribeirão Preto, in an area primitively covered with transitional forest, now heavily under agriculture; 8 specimens.

The remaining specimens (or "small samples"), one to three per locality, are referred to by the locality name, with the exception of two examples from the coast of S. Paulo (S. Vicente and Ilha de S. Sebastião), quoted together as "Littoral of S. Paulo".

The distances between the localities grouped together will serve as an indication of the coarseness of the geographical analyses.

METHODS

Many of our specimens were previously used by Gans (1964) in his monograph. I checked the consistency of our respective systems of counting scales and of measuring body and tail length. Agreement was found to be practically perfect; thus, in the case of specimens no longer available, I use Gans's published data without further mention of the fact.

I took body and tail measurements with a steel ruler, to the nearest millimeter. Both head measurements were taken with calipers, under magnification, to the nearest tenth of a millimeter. Head length was measured on the side of the head, between the front edge of the first body annulus and the tip of the snout. Head width is maximum width of the head, taken with care not to compress the musculature. Both measurements were abundantly checked and found to be reliable.

Statistical methods, purposefully simples and straightforward, were done after Silva-Leme (1959, 1972), except for simultaneous comparisons of statistics, where I used Kramer's (1956) extension of Duncan's (1955) method, which seems to me the best in the absence of experiment-wise error, with emphasis, on the contrary, on individual contrasts.

ANALYSIS

MERISTIC CHARACTERS

Body annuli. Tables 1 and 2 show marked geographic differentiation of the number of body annuli. Analysis of variance shows the differences to be statistically significant ($n_1 = 4$, $n_2 = 36$, $F = 14.893^{***}$). Simultaneous comparison of the means identifies two groups of samples: on one side, S. Paulo, Botucatu* and Ribeirão Preto, with means between 251.5 and 252.9; on the other Pierópolis* and Emas*, with means of 242.0 and 244.0 annuli. Table 1 further shows that the small samples may be thus apportioned: Avanhandava, littoral S. Paulo, Santa Rita, Piau and Chaves, and very probably also Ilha Solteira, on the high counts side; Rio Verde on the side of low counts.

Tail annuli. A chi square test applied to the five major samples affords $X^2 = 16.201$, between the 10 and the 5% levels of significance. Grouping the samples with high body annuli counts against those with low numbers results in $X^2 = 8.2445$ ($n = 3$), significant at the 5% level. Introducing the small samples into their respective groups yields exactly the same results ($X^2 = 10.5852$, $n = 4$).

Total number of annuli. The counts of body and tail annuli are not significantly correlated within the samples. This leads to the investigation of the distribution of the total number of annuli, body plus tail, which is indeed a logical variable to study in a serpentine reptile without tail autotomy. Table 3 shows considerable geographical variation of this character; analysis of variance confirms the heterogeneity ($n = 4$, $n = 36$, $F = 13.742^{***}$). Simultaneous comparison of the means affords the same grouping found in the case of body annuli: Botucatu*, S. Paulo and Ribeirão Preto with high counts (means 270.3 to 270.9), Emas* and Peirópolis* with low counts (260.1 and 261.2). The small samples are distributed as in the previous cases: Ilha Solteira, Avanhadava, Littoral S. Paulo, Chaves, Santa Rita and Piau with high numbers, Rio Verde with a low one.

In spite of the absence of correlation between body and tail annuli, I think, given the body shape of the amphisbaenids, it more advisable to consider all counts of annuli as a single character, not as three individual characters.

Segments to a midbody annulus. A first care in analyzing this character is to check the eventual presence of correlation between the numbers of dorsal and ventral segments. Regression analysis done both within the samples and with all specimens combined shows that the two counts are statistically independent.

Applying a chi square test to the numbers of segments in the major samples affords, in all cases, values of X^2 with probabilities between 10 and 5%. The suggested groupings of localities neither agree among themselves nor make geographical or ecological sense; the matter is therefore dropped as inconclusive.

BODY PROPORTIONS

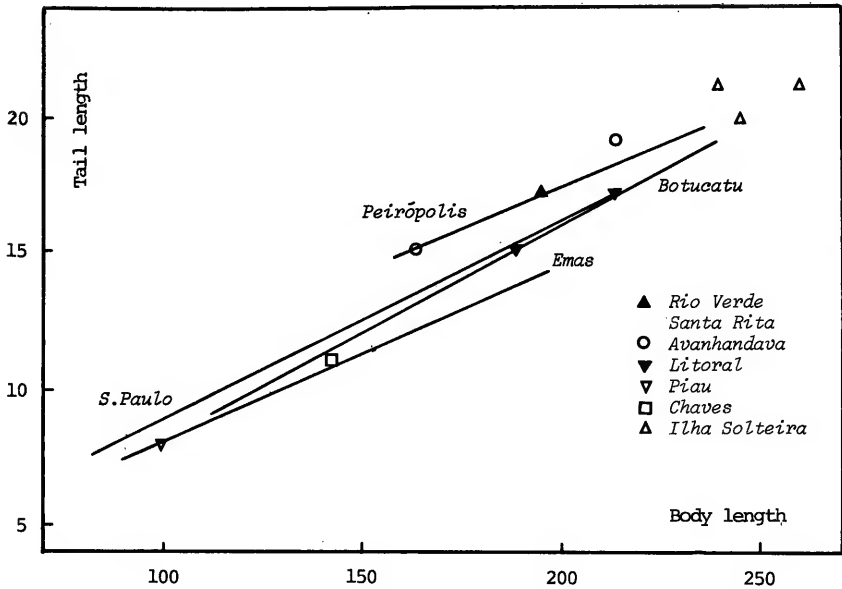
Tail length. The absence of autotomy grants a welcome chance of studying tail length in an amphisbaenid.

The regression of tail length on body length results in three groups (Graph 1), the lines being parallel but characterized by their intercepts: Peirópolis*, with a long tail, Ribeirão Preto, Botucatu* and S. Paulo with intermediate ones, and Emas*, definitely short tailed. As to the small samples, Rio Verde, Avanhadava and Santa Rita fall in with Peirópolis*, Chaves and Piau with Emas*.

Head width. I believe the regression of head width on total body length to be the best measure of attenuation in serpentine reptiles (Schmidt, 1977), although it is rarely investigated, given the frequency of autotomy. As could be predicted (Table 7), the regressions of this character show excellent fits, no coefficient of determination being smaller than 0.95. Analysis of variance shows that the larger samples fall in two groups, one composed of Botucatu alone, with very elongate bodies (i.e., relatively narrow heads) and the other composed of all the remaining large samples. Chaves, Piau and Santa Rita closely agree with Botucatu, the remainder small samples with the large group.

The regressions of head width on head length vary much in quality, from a very low coefficient of determination (0.6089, Peirópolis*) to normal values (0.9723, Emas*). Analysis of variance reveals no significant heterogeneity in the materials. Combining all specimens in a single regression yields an intercept not significantly different from zero and a regression coefficient of 0.73, meaning that head width is on the average 73% of head length.

Head length. The regression of head length on trunk length shows geographical differentiation: all lines may be considered as parallel, but there are significant differences in the intercepts. The differences do not lead to a clear grouping, however. On one extreme is Peirópolis, with an elongate head, on the other Ribeirão Preto and Botucatu, with short heads. S. Paulo and Emas agrees with both extremes, bridging the gap.



Graph 1. *Amphisbaena roberti*, geographical samples. Regression of tail length on body length.

THE RELATIONSHIP BETWEEN TAIL LENGTH AND NUMBER OF BODY ANNULI

The suggested relationship between number of body annuli and tail length is apparently a result of the concordance between S. Paulo, Botucatu and Ribeirão Preto. In order to further investigate this relationship it is necessary to find a proxy for tail length, i.e., to find a single number capable of representing the character in a given sample. I tried two ways.

First I computed, for each sample, the tail lengths corresponding to an approximately minimal and to a maximal body lengths for the whole materials at hand: 90mm and 240mm. Then I computed Spearman's coefficient of rank correlation between the mean number of body annuli and these calculated tail lengths. In both cases the coefficients were not significant: -0.525 and -0.175, for $n = 5$.

Additionally, considering that the coefficients of regression of the several samples were homogeneous, I calculated a general coefficient and, using this, new intercepts for all samples. Correlation between the means of body annuli and these new intercepts also failed to reach the level of significance (-0.400 for $n = 5$).

CONCLUSION

Two characters show clear-cut geographical differentiation in our samples, exactly those initially stressed by Gans, number of annuli and tail length. Summarizing (Table 8) these patterns, one sees just one common denominator: S. Paulo, Botucatu and Ribeirão Preto agree in both cases. The remainder form a veritable mosaic.

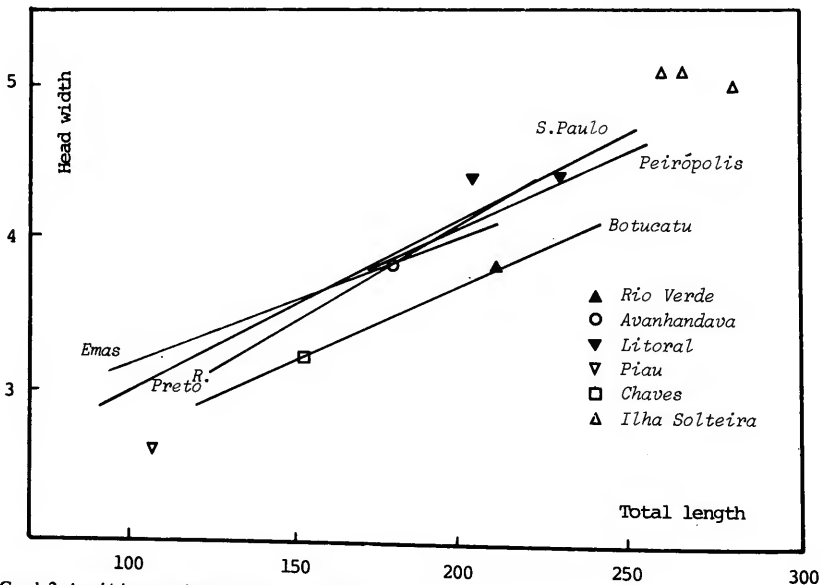
Looking at the general ecology of the localities does not help. *A. roberti* is seen to be remarkably euryoecic. Five of the available localities are undisputably under cerrado: Peirópolis, Emas, Piau, Santa Rita do Araguaia and Rio Verde. All are in the great core area of the cerrados (Ab' Saber, 1977), with the exception of Emas, which is in a small enclave among transitional forests in S. Paulo. Contrariwise, Chaves, Ilha de S. Sebastião and S. Vicente are under Atlantic forest.

The other localities are in complex areas and much disturbed by man, but their main original avocation can be securely conjectured (Chiarini and Coelho, 1969). S. Paulo, Ribeirão Preto and Avanhandava were in the transitional forest of the state of S. Paulo, between the Atlantic forest ("tropical broadleaved forest") and the Central Brazilian cerrados. I personally consider these forests an ecological extension of the Atlantic Forest. Botucatu is on the contact between the transitional forests and a cerrado enclave. It seems clear that the strongest case is for a mosaic pattern, occupying a broad range of ecologies. This probably indicates low overall densities, and restricted gene flow between isolated populations.

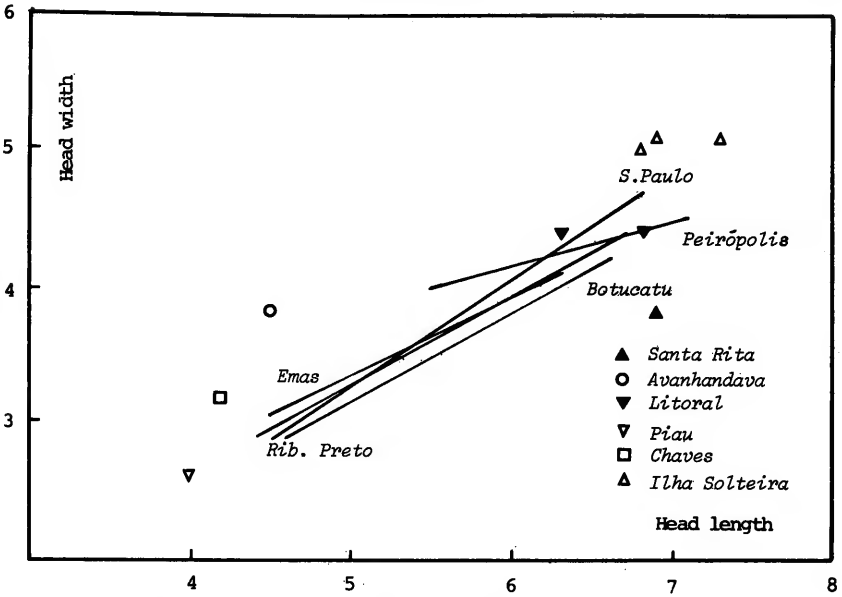
In spite of the great geographical range of *A. roberti*, most specimens (all but four) come from the state of S. Paulo and adjacent Minas Gerais and Goiás. We have a good representation of Brazilian amphisbaenids and I am inclined to think that this geographic concentration is real. The amount of variation found in this limited area (some 150,000 sq km) is strikingly large. Take, for instance, tail length (Graph 1): the overland distance between the extreme samples, Peirópolis and Emas, is 250 km. In the case of head width (Graphs 2 and 3) the analogous distance is 185 km, S. Paulo to Botucatu; in the case of head length it is 350 km (Graph 4, Peirópolis to Botucatu) and in the case of number of body annuli (Table 1) it is 160 km (Botucatu to Emas).

This, as I see it, much reinforces the idea of a mosaic pattern, stemming from a uneven distribution with limited gene flow between populations.

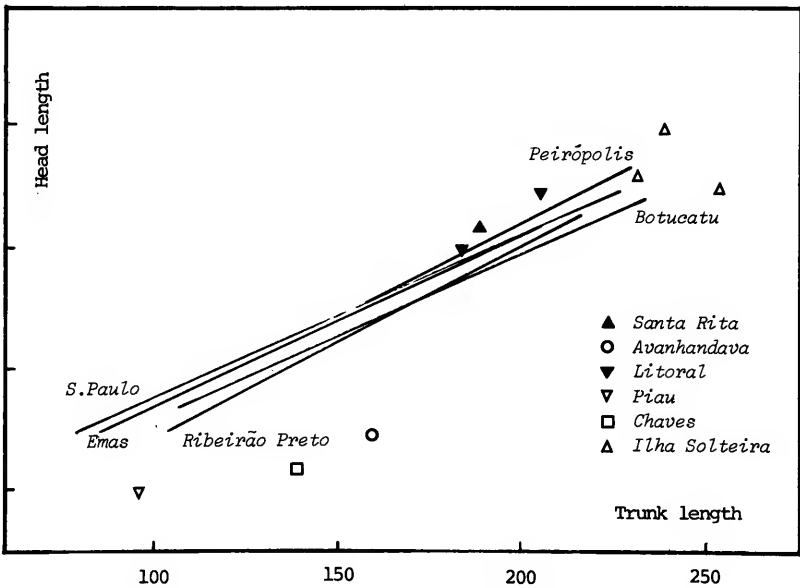
A last comment in support of this pattern comes from the northernmost record of the species, Piau in northern Tocantins, some 1,000 km from the core area the species. The only specimen known fits neatly into the mosaic pattern.



Graph 2. *Amphisbaena roberti*, geographical samples. Regression of head width on total length.



Graph 3. *Amphisbaena roberti*, geographical samples. Regression of head width on head length.



Graph 4. *Amphisbaena roberti*, geographical samples. Regression of head length on trunk length.

Table 1. *Amphisbaena roberti*, body annuli, geographical samples.

	Rio Verde	Peirópolis*	Ilha Solteira	Avanhandava	Ribeirão Preto	Emas*	Botucatu*	S. Paulo, SP	Litoral	Santa Rita	Chaves	Piau
235		1										
236		-										
237		-										
238		1										
239		-										
240		1				1						
241		-				-						
242		3				2		1				
243		2				2						
244	1				1	-						
245		1				1						
246		2			1	1						
247			1		1	1		-				
248			1		1	1	1					
249			-				-			1		
250			-									
251			-									
252			1					1				
253			-				3	1	1			
254			-		1		2		1		1	
255							1	2				
256					1			-				
257					1			1				
258												
259					-							
260					1							
261												
262					-							
263												
264				1								
265												

Table 4. *Amphisbaena roberti*, total number of annuli (body plus tail), geographical samples.

	Rio Verde	Peirópolis*	Ilha Solteira	Avanhandava	Ribeirão Preto	Emas*	Botucatu*	S. Paulo, SP	Litoral	Santa Rita	Chaves	Piau
252		1										
253		-										
254		-										
255		-										
256		1										
257		1				1						
258		-				-						
259		1				2		1				
260		2				1		-				
261		2				1		-				
262		-			1	1		-				
263		-			-	-		-				
264		1			-	2		-				
265	1	1			-	1		-				
266		1	1		1		1	-				
267		-	-		1		-	-				
268		-	1		-		-	-				
269		-	-	1			-	-		1		
270		-	-	-			-	-				
271		-	-	-			2	1				
272		-	-	-	1		4	1	2			
273		-	1	-	-			1				1
274		-	-	-	1			1				
275		-	-	-	-			1				
276		-	-	-	1			1				
277		-	-	-	-			-				
278		-	-	-	-			-				
279		-	-	-	1			-				
280		-	-	-	-			-				
281		-	-	-	-			-				
282		-	-	1	-			-				
283		-	-	-	-			-				
284		-	-	-	-			-				

Table 5. *Amphisbaena roberti*, total number of annuli, statistics of the geographical samples.

		R	\bar{x}	s	V	I(\bar{x})
Rio Verde	1	265				
Peirópolis*	11	252 - 266	260.1 ± 1.24	4.11	1.58	257.3 - 262.9
Ilha Solteira	3	266 - 273	269.0			
Avanhandava	2	269 - 282	275.5			
Ribeirão Preto	8	262 - 279	270.3 ± 2.08	5.87	2.17	265.3 - 275.2
Emas*	9	257 - 265	261.2 ± 0.91	2.73	1.04	259.1 - 263.3
Botucatu*	7	266 - 272	270.9 ± 0.83	2.19	0.81	268.8 - 272.9
S. Paulo, SP	6	259 - 275	270.7 ± 2.40	5.89	2.18	264.5 - 276.8
Litoral	2	272	272.0			
Santa Rita	1	269				
Chaves	1	272				
Piau	1	284				

Table 6. *Amphisbaena roberti*, segments to a midbody annulus, geographical samples.

	Rio Verde	Peirópolis*	Ilha Solteira	Avanhandava	Ribeirão Preto	Emas*	Botucatu*	S. Paulo, SP	Litoral	Santa Rita	Chaves	Piau
	Dorsals											
14	1	6	2	1	5	2	2	1	1		1	1
15		3		-	1	-	1	-	-			
16		2	1	1	1	7	4	4	1	1		
	Ventrals											
12		1					1					
13		2					-					
14	1	7	1	2	3	7	6	5	2			1
15		1	-		2	1						
16			2		2	1				1		
	Sum											
26		1										
27		2										
28	1	3	1	1	1	1	3	1	1		1	1
29		2	-	-	3	1	1	-	-			
30		3	1	1	3	3	3	4	1			
31			-									
32			1		1					1		

Table 7. *Amphisbaena roberti*, statistics of the regression analyses.

	N	R(x)	R(y)	b	a	r ²
Tail length x Body length						
Peirópolis*	10	159 - 236	15 - 20	0.062 ± 0.0065	5.02 ± 1.332	0.9187
Ribeirão Preto	7	109 - 223	10 - 18	0.073 ± 0.0028	1.75 ± 0.472	0.9927
S. Paulo	6	83 - 233	8 - 19	0.072 ± 0.0093	1.73 ± 1.806	0.9387
Botucatu*	6	112 - 239	9 - 19	0.079 ± 0.0071	0.36 ± 1.330	0.9682
Emas*	9	90 - 197	7 - 14	0.065 ± 0.0064	1.50 ± 1.091	0.9374
Head width x Total length						
Peirópolis*	9	174 - 255	3.8 - 4.6	0.0099 ± 0.00082	2.08 ± 0.179	0.9545
Emas*	5	97 - 211	3.1 - 4.1	0.0086 ± 0.00072	2.28 ± 0.132	0.9791
Botucatu*	6	121 - 243	2.9 - 4.1	0.0098 ± 0.00138	1.70 ± 0.260	0.9618
Ribeirão Preto	7	125 - 223	3.0 - 4.3	0.014 ± 0.0011	1.36 ± 0.192	0.9672
Head width x Head length						
S. Paulo	4	4.5 - 6.5	2.9 - 5.0	0.91 ± 0.163	-1.20 ± 1.237	0.9396
Ribeirão Preto	7	4.4 - 6.4	3.0 - 4.3	0.72 ± 0.082	-0.25 ± 0.446	0.9391
Emas*	7	4.5 - 6.0	3.1 - 4.3	0.64 ± 0.062	-0.25 ± 0.348	0.9723
Botucatu*	5	4.6 - 6.3	2.9 - 4.1	0.76 ± 0.108	-0.64 ± 0.604	0.9436
Peirópolis*	9	5.5 - 6.8	3.8 - 4.6	0.41 ± 0.124	1.70 ± 0.770	0.6089
Head length x Trunk length						
Peirópolis*	10	153.5 - 229.5	5.5 - 6.8	0.016 ± 0.0042	3.05 ± 0.837	0.6457
S. Paulo	4	78.5 - 226.5	4.5 - 6.5	0.014 ± 0.0030	3.42 ± 0.057	0.9991
Emas*	5	85.5 - 191.0	4.5 - 6.0	0.014 ± 0.0012	3.26 ± 0.199	0.9790
Ribeirão Preto	7	104.2 - 216.6	4.4 - 6.4	0.015 ± 0.0021	2.95 ± 0.344	0.9143
Botucatu*	5	107.4 - 232.8	4.6 - 6.3	0.014 ± 0.0013	3.19 ± 0.234	0.9745

N, individuals in sample. R(x), R(y), ranges of the variables. b, slope (regression coefficient). a, intercept (regression constant). r², coefficient of determination.

Table 8. *Amphisbaena roberti*, summary of geographical differentiation.

		Number of annuli		
		High	Low	
Large samples	S. Paulo		Peirópolis*	
	Botucatu*		Emas*	
	Ribeirão Preto			
Small samples	Piau		Rio Verde	
	Santa Rita			
	Ilha Solteira			
	Avanhandava			
	Littoral			
	Chaves			
		Tail length		
		Long	Intermediate	Short
Large samples	Peirópolis*		S. Paulo	Emas*
			Botucatu*	
			Ribeirão Preto	
Small samples	Santa Rita		Litoral	Piau
	Rio Verde			
	Ilha Solteira			
	Avanhandava			

APPENDIX. Specimens used.

Note: BL, body length. TL, tail length. HL, head length. HW, head width. BA, body annuli. TA, tail annuli.
*, paratype. **, holotype.

MZUSP	Locality	BL	TL	HL	HW	BA	TA	Segments
State of Tocantins								
4050	Piau	100	8	4.0	2.6	265	19	12-14:14
State of Goiás								
69857	Santa Rita do Araguaia	195	17	6.6	3.8	249	20	16:16
3372	Rio Verde	195	17	-	-	244	20	14:14
State of Minas Gerais								
13733	Peirópolis	159	15	5.5	3.8	242	19	14:14
13734	"	188	16	5.5	4.1	243	18	14:13
13730	"	190	17	6.5	4.1	235	17	16:14
13732	"	198	18	6.3	4.2	240	17	14:13
13736	"	201	17	5.8	4.3	242	17	14:14
13731	"	223	19	6.7	4.5	242	18	14:14
13729	"	226	19	6.8	4.6	243	17	15:14
13737	"	233	20	6.9	5.1	238	18	14:12
13728	"	236	19	6.5	4.5	246	19	16:14
4636	Uberlândia	179	16	5.9	4.0	245	19	14-15:15
4637	"	180	18	6.2	4.2	246	20	14-15:14
State of Espírito Santo								
36589	Chaves	143	11	4.2	3.2	254	18	14:14
State of S. Paulo								
755*	S. Paulo	83	8	4.5	2.9	255	19	14-16:14
1937*	"	159	13	-	-	252	19	14-16:14
1946**	"	207	115	6.2	4.3	257	18	15-16:14
1947*	S. Paulo	217	19	-	-	253	19	14-16:14
1257	"	233	19	6.5	5.0	255	18	- -
6435	Poá	228	18	6.5	4.5	242	17	14:14
8426	S. Vicente	212	17	6.5	4.4	254	18	14-16:14
1253	Ilha de S. Sebastião	189	15	6.0	4.4	253	19	14:14
6434	Rio Claro	197	14	6.0	4.0	240	17	14:15
2672	Leme	185	14	-	-	242	17	14-16:18
1928	Emas	90	7	4.5	3.1	242	17	14:14
6449	"	135	11	-	-	243	18	14-16:14
2674	"	174	13	5.6	3.0	247	17	14-16:14
7119	"	178	12	5.6	3.9	248	17	14-16:14
7120	"	182	13	-	-	246	18	16:16
2675	"	183	14	-	-	245	17	14-16:14
7669	"	190	14	6.0	4.1	243	17	14-16:14
2523	Botucatu	112	9	4.6	2.9	255	17	14-16:12
45810	"	172	13	5.5	3.6	248	18	14:14
1930	"	172	15	-	-	253	19	14-16:14
1932	"	174	14	5.5	3.4	253	19	14:14
1935	"	214	18	6.0	4.1	253	18	14-16:14
2524	"	225	18	6.3	4.1	254	17	14-15:14

APPENDIX (cont.)

42690	Avaré	239	19	6.2	5.0	254	18	16:14
60608	Ribeirão Preto	-	-	-	-	244	18	14:16
60610	"	109	10	4.8	3.0	246	20	14:16
60609	"	115	10	4.4	3.0	247	19	14:15
60606	Ribeirão Preto	146	12	5.2	3.5	256	18	15:14
36952	"	181	15	5.6	3.8	254	18	-
60603	"	186	15	5.6	3.9	257	19	14:14
60605	"	192	16	5.9	4.0	248	19	16:14
60604	"	223	18	6.4	4.3	260	19	14:15
1261	Avanhandava	164	15	4.5	3.8	264	18	13-14:14
6526	"	214	19	-	-	252	17	14-16:14
42770	Ilha Solteira	239	21	6.6	5.1	248	20	16:16
42771	"	245	20	7.0	5.1	252	21	14:16
42773	"	260	21	6.5	5.0	247	19	14:14

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