Morphological Variation between the endemic *Anolis oculatus* **and the invasive** *Anolis cristatellus*

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Abstract

Anolis oculatus is an endemic species of lizard that has survived hurricanes, volcanoes, and tropical storms on the island of Dominica for centuries. Within the past few years a menace has made its way to the island posing more of a threat than any force of nature. The invasive *Anolis cristatellus,* or Puerto Rican crested anole, is a close relative of *A. oculatus* and up until the past decade was nonexistent on Dominica. *A. cristatellus* is extremely adaptable and more aggressive than *A. oculatus*. *A. cristatellus* has already pushed the endemic lizard out of many dry coastal areas. Without management there is evidence that *A. oculatus* numbers will plummet drastically in most parts of the island. The purpose of this experiment is to determine if there are any morphological differences between these two anole species that might help explain the abrupt invasion of *A. cristatellus*. Over the course of two weeks 15 *A. oculatus* and 12 *A. cristatellus* were captured and measured in order to find differences in their morphology. I recorded head length, head width, hind leg length, hind foot length, SVL, and tail length. At the end of this study I was able to determine that there are in fact differences in the morphology of these two species. The results presented in this paper may help lead to a strategy for resistance of the invasive Puerto Rican crested anole.

Introduction

Up until around the turn of the century the *Anolis oculatus* was the only *Anolis* lizard on Dominica. The last major study of *A. oculatus* was done in 1992 by Malhotra and Thorpe. They found that they were present in all parts of the island. Since then there has been a worrying trend in the southwestern part of the island. Sometime between 1997 and 2002 *Anolis cristatellus* established itself as an invasive species in Dominica (A. Malhotra et al 2007).

In Sammy Reinhart's survey performed in 2010, she found that *A. cristatellus* had completely invaded the Botanical Gardens where A. oculatus used to be commonly found. However, *A. cristatellus* seemed to stay contained to this dry forest of Dominica, and no other *A. cristatellus* was found in any other part of the island. It is unlikely that the two species of anole will ever be able to coexist in the same environment. The long term prognosis for the native *A. oculatus* may be eradication from the majority of the island, even in environments were *A. oculatus* has advantages over *A. cristatellus* (A. Malhotra et al. 2007). Studying and observing the relationship between these two species needs to begin now in order to ensure the existence of the endemic *A. oculatus*.

Materials and Methods

Every specimen studied was caught by hand. A team of at least two to three people was ideal for this experiment: one person to hold the anole, someone to take the measurements, and someone to record the data and take photographs. A caliper was used to take measurements of the length of skull, width of skull, length of hind leg, length of hind foot, snout to vent length, and tail length. Measurements were taken to the nearest tenth millimeter. A picture of each specimen was also taken. SPSS version 18 was the software used for the analysis. A descriptive analysis, discriminant analysis, and analysis of variance was used in my research project.

Specimens were taken from three different sites. *A. oculatus* were found at Batalie Beach and at Cabrits National Park. All of the A. cristatellus were found at the Botanical Gardens. A method for catching anoles was developed during this experiment. They are easiest to catch when they are facing downward. It is best to come up from behind so that they do not see you, because as soon as they see a threat they will retreat up out of reach. You must grab them in one quick unhesitant motion. Keep in mind that if you grab them by the tail they have a defense mechanism that detaches their tail. Many failed attempts contributed to forming this method for capturing these allusive anoles.

Results

Table 1. Morphological Measurements of all *Anolis* used in this study

Anole	Species	SP Code	Length of Skull	Width of Skull	Hind Limb Length	Hind Foot Length	SVL	Tail Length
1	Oculatus	1	25.8 mm	13.4 mm	50.9 mm	20.9 mm	73.2 mm	134.9 mm
2	Oculatus	1	16.7	8.9	35.3	14.5	53.7	74.4
3	Oculatus	1	16.5	9.9	38.7	15.7	54.9	84.9
4	Cristatellus	2	22.1	13.3	48	17.6	68.3	131.8
5	Cristatellus	2	19.9	11	45.8	15.2	66.5	140.8
6	Oculatus	1	18.3	12.9	50	28.5	66.5	140.8
7	Oculatus	1	22.8	15	53.2	21.2	79	120.8
8	Oculatus	1	14.9	10.1	41.7	17	53.5	103.8
9	Oculatus	1	21.8	13.9	44	20.2	66.2	123
10	Oculatus	1	21.9	12	48.7	18.2	60.8	85.1
11	Oculatus	1	22.6	13.2	48.3	19.2	66.4	124.1
12	Oculatus	1	22.4	13.3	44.6	19.6	72.1	123.2
13	Oculatus	1	21.9	12.6	47.2	19	63	133.1
14	Oculatus	1	21	12.1	50.7	20	68.5	133.5
15	Oculatus	1	21	12.5	47	17.6	65.9	123.2
16	Oculatus	1	31.2	16.6	62	25.4	90.1	180.4
17	Cristatellus	2	20	11	45.1	18.2	63	85.7
18	Cristatellus	2	19	10.4	46.9	17.3	61.9	118.5
19	Cristatellus	2	18.4	12.6	47.6	19.4	58.7	81.9
20	Cristatellus	2	22.1	13.9	54.9	21.8	72	116.8
21	Oculatus	1	22	12.9	46.3	18.2	65.9	NA
22	Cristatellus	2	19.4	12.4	46.6	20	66.4	133.2
23	Cristatellus	2	17.2	12.7	46.3	15.2	63.2	112.2
24	Cristatellus	2	19.4	15	51	18.6	65	105.9
25	Cristatellus	2	17.9	12.6	51.9	22.4	70.2	117.7
26	Cristatellus	2	17.3	11.8	42.4	17.3	70.8	94.2
27	Cristatellus	2	20.8	14.4	48.5	18.7	68	98.2

Table 2. Descriptive Analysis: *Anolis oculatus*

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Length_Skull	15	14.9	31.2	21.387	3.9560
Width_Skull	15	8.9	16.6	12.620	1.9450
Hind_Limb	15	35.3	62.0	47.240	6.2918
Hind_Foot	15	14.5	28.5	19.680	3.5249
SVL	15	53.5	90.1	66.647	9.6588
TL	14	74.4	180.4	120.371	27.0235
Valid N (listwise)	14				

Table 3. Descriptive Analysis: *Anolis cristatellus*

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Length_Skull	12	17.2	22.1	19.458	1.6451
Width_Skull	12	10.4	15.0	12.592	1.4087
Hind_Limb	12	42.4	54.9	47.917	3.3414
Hind_Foot	12	15.2	22.4	18.475	2.2312
SVL	12	58.7	72.0	66.167	3.9771
TL	12	81.9	140.8	111.408	18.8456
Valid N (listwise)	12				

Table 2 and 3 present all of the data as minimum and maximum length for all six variables for each species. The tables also present averages and standard deviations for each species. Table 2 shows 14 instead of 15 for tail length due to one specimen with no tail.

Table 4: Discriminant Analysis

a.

Standardized Canonical Discriminant Function Coefficients

	Function
	1
Length_Skull	1.779
Width_Skull	-.159
Hind_Limb	-1.617
Hind_Foot	1.161
SVL	-.931
TL	.287

b.

Functions at Group Centroids

SPCode	Function
	1
1	.816
2	-.952

Table 4a presents the loadings of the variables on the discriminant function. Table 4b is the loadings of the group centroids for *A. oculatus* (1) and *A. cristatellus* (2).

Table 5. Analysis of Variance

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.543	12.820	6	.046

Table 5 shows the test of significance of the discriminant function derived in the analysis. The function explained significant multivariable differences between species (P= 0.046).

Table 6.

Classification Results[a]

		SPCode	Predicted Group Membership		Total
			1	2	
Original	Count	1	12	3	15
		2	3	9	12
	%	1	80.0	20.0	100.0
		2	25.0	75.0	100.0

a. 77.8% of original grouped cases correctly classified.

Table 6 shows that only 3 *A. oculatus* and 3 *A. cristatellus* were wrongly categorized due to their morphology during the classification procedure.

Table 7.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Length_Skull	Between Groups	24.790	1	24.790	2.490	.127
	Within Groups	248.866	25	9.955		
	Total	273.656	26			
Width_Skull	Between Groups	.005	1	.005	.002	.967
	Within Groups	74.793	25	2.992		
	Total	74.799	26			
Hind_Limb	Between Groups	3.053	1	3.053	.113	.740
	Within Groups	677.033	25	27.081		
	Total	680.085	26			
Hind_Foot	Between Groups	9.680	1	9.680	1.058	.313
	Within Groups	228.707	25	9.148		
	Total	238.387	26			
SVL	Between Groups	1.536	1	1.536	.026	.873
	Within Groups	1480.084	25	59.203		
	Total	1481.620	26			
TL	Between Groups	519.101	1	519.101	.930	.345
	Within Groups	13400.218	24	558.342		
	Total	13919.319	25			

Table 7 gives the ANOVA variable by variable. None of the variables were significantly different. (< 0.05)

Discussion

After running the SPSS data analysis software, I had very interesting results. Table1 includes the primary data that was collected in the field. Table 2 and Table 3 presents the descriptives for both species. When looking at the average lengths for *A. oculatus* versus *A. cristatellus*, table 2 and table 3 show that there is hardly any difference between the two. The two largest differences were at *A. oculatus'* tail length at 8.963 mm more on average and skull length was 1.929 mm more. All of the other variables were under 1.0 mm in difference. Tail length may also vary because the tail may have been recently broken or just started growing back. Table 4 b. is the key for figure 4 a., SP1 (*A. oculatus*) have positive scores on the discriminant function and SP2 (*A. cristatellus*) have the negative scores. *A. oculatus* have a longer skull, longer hind feet, and slightly longer tails. *A. cristatellus* have slightly wider skulls, longer hind legs, and a slightly longer snout to vent. Table 5 is the overall test of significance chart. What it shows is that when putting all six dimensions together a significant difference of (0.046) is present. Any probability value under 0.05 is significant. Table 6 shows that the classification procedure only wrongly placed 6 out of the 27 specimens in the wrong species. SPSS could accurately place the specimens in the right categories solely based on the morphological data. Table 7 shows the variable by variable tests of significance using ANOVA. It is very interesting because when each variable is looked at individually every P value is way over 0.05 showing that there is no significant difference.

My initial hypothesis was not supported by the data and analyses. There are in fact morphological differences between the *A. oculatus* and the *A. cristatellus*. The discriminant analysis (table 4) and the Wilks' Lambda (table 5) are the best proof that these two species have different morphological traits. Perhaps the most interesting data from the SPSS was table 7. When looking at each variable between the groups it shows that there is no significance. This is a classic example of Rao's paradox. The main error that could have occurred during this study is not getting accurate measurements. The measurements may be off by a few millimeters. When looking back over my data I found that I had captured the same anole twice. I was able to catch the mistake before the data sets were used for this project. If I could of done anything different I would of collected more specimens and even more data to work with.

The *A. oculatus* appearance changes in different habitats. In the rain forest they are typically a shade of green with bluish spots. On the east coast they will be a more orange or brown color with scattered white spots, and they also has a very deep tail crest. On the west coast they are much smaller and paler and commonly can be confused with *A. cristatellus*. In the south they will typically be a plain color while in the north they will have extensive coloration and patterns and have black patches on their sides (Malhotra and Thorpe 1999). When I was collecting I found that *A. oculatus* has a dewlap that is all yellow or orange and commonly has a white dot right in the center of their skull. While on the field, I observed that *A. cristatellus* have less coloration, being more of a brownish tone. The males also have large crests on there head and their dewlaps are yellow with green in the center. Visually you can also see that the skull is more of a box shape and not as elongated as the *A. oculatus*. Just in the few weeks of studying these anoles I could determine major behavioral differences between these two species. There is a reason why there are less *A. cristatellus* specimens in this study. Their behavior makes capturing them a considerably harder task. Compared to *A. oculatus*, as soon as you approach them *A. cristatellus* are quick to move high up into the trees making them very hard to catch. Once you catch them they are much more aggressive than the endemic species. Out of the fifteen A. oculatus studied not one bit me or defecated on me. Every *A. cristatellus* I found was attempting to bite, defecate, and squirm out of my hand to get away. Their behavior may also be a clue as to way *A. cristatellus* is flourishing so rapidly. All anoles are active during the day, however most activity will be seen at dawn and dusk when they are hunting. At night they will be found out of reach in the trees to avoid predators (Malhotra and Thorpe).

Conclusions

After doing this study it is clear that the morphology and behavior of the endemic *A. oculatus* and the invasive *A. cristatellus* are significantly different. Hopefully, this study well help researchers learn how and why this invasive species is able to encroach on *A. oculatus'* territory. *A. cristatellus* invasion of Dominica needs to be monitored and contained. Otherwise, it may be the only species of anole left on the island of Dominica.

Works Cited

Malhotra, Anita, Roger S. Thorpe, Eric Hypolite, and Arlington James. A Report on the Status of the Herptofuana of the Commonwealth of Dominica, West Indies. Applied Herpetology 4 (2007): 177-94.

Malhotra, Anita and Roger S. Thorpe. Reptiles and Amphibians of the Eastern Caribbean. London: Macmillan Education Ltd, 1999. 20-31.

Reinhart, Sammy. 2010. A survey and discussion of the invasion of *Anolis cristatellus* and its effects on the endemic *Anolis oculatus*. Texas A&M University Study Abroad Dominica.

1

Species: Oculatus
Locality: Batalie Beach

2

Species: Oculatus
Locality: Batalie Beach

3

Species: Oculatus
Locality: Batalie Beach

4

NA

Species: Cristatellus
Locality: Botanical Garden

5

Species: Cristatellus
Locality: Botanical Garden

6

Species: Oculatus
Locality: Middleham Falls

7

Species: Oculatus
Locality: Middleham Falls

8

Species: Oculatus

Locality: Middleham Falls

9

Species: Oculatus
Locality: Cabrits

10

Species: Oculatus
Locality: Cabrits

11

Species: Oculatus
Locality: Cabrits

12

Species: Oculatus
Locality: Cabrits

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Species: Oculatus
Locality: Cabrits

14

Species: Oculatus
Locality: Cabrits

15

Species: Oculatus
Locality: Cabrits

16

Species: Oculatus
Locality: Cabrits

17

Species: Cristatellus
Locality: Botanical Garden

18

Species: Cristatellus
Locality: Botanical Garden

19

Species: Cristatellus
Locality: Botanical Garden

20

Species: Cristatellus
Locality: Botanical Garden

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Species: Oculatus
Locality: Botanical Garden

22

Species: Cristatellus
Locality: Botanical Garden

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Species: Cristatellus
Locality: Botanical Garden

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Species: Cristatellus
Locality: Botanical Garden

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Species: Cristatellus
Locality: Botanical Garden

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Species: Cristatellus
Locality: Botanical Garden

27

Species: Cristatellus
Locality: Botanical Garden