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Original Article

Do restinga cnemidophorine lizards run on empty along the Brazilian coast?

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Abstract

The number of individuals with empty stomachs in a population (*i.e.* the proportion of individuals "running on empty") can be used as a simple index of instantaneous energy balance of some organisms such as lizards and fishes. In this study, we aimed to analyze the proportion of empty stomachs in 16 populations of five cnemidophorine species (*Glaucomastix abaetensis, Ameivula ocellifera, Glaucomastix littoralis, Contomastix lacertoides* and *Ameivula nativo)* along approximately 5,000 km the Brazilian coast. A total of 550 individuals had their stomach contents removed and identified in the laboratory. Our results showed that the proportion of individuals "running on empty" varied from 0 to 11.1% among the different populations and species. These proportions are suggestive that the five studied species would be in an overall positive energy balance at the time of the study.

Keywords: energy balance, run on empty, lizards, cnemidophorine, Teiidae.

Os lagartos cnemidophorine de restinga correm no vazio ao longo da costa brasileira?

Resumo

O número de indivíduos com estômagos vazios em uma população (*i.e.* a proporção de indivíduos "correndo no vazio") pode ser usado como um índice simples do balanço energético instantâneo de organismos como lagartos e peixes. Este estudo teve como objetivo analisar a proporção de estômagos vazios em 16 populações pertencentes a cinco espécies de cnemidophorines (*Glaucomastix abaetensis, Ameivula ocellifera, Glaucomastix littoralis, Contomastix lacertoides* e *Ameivula nativo*) ao longo de cerca de 5,000 km da costa leste do Brasil. Um total de 550 indivíduos tiveram seus conteúdos estomacais removidos e analisados em laboratório. Nossos resultados mostraram que a proporção de indivíduos "correndo no vazio" variou entre 0 a 11.1% entre as diferentes populações e espécies. Essas proporções sugerem que as cinco espécies estudadas estariam em geral em um balanço energético positivo, quando da realização deste estudo.

Palavras-chave: balanço energético, correndo no vazio, lagartos, cnemidophorines, Teiidae.

1. Introduction

The proportion of individuals having empty stomachs should indicate the energy balance of a given population (Huey et al., 2001). Since then, the number of individuals "running on empty" in a population has been used as a simple index of instantaneous energy balance of organisms such as lizards (Huey et al., 2001) and fishes (Arrington et al., 2002). Before organisms can grow and reproduce, they must first acquire energy to achieve their maintenance requirements (Schoener, 1971). According to Huey et al. (2001), individuals with empty stomach are potentially on a negative instantaneous energy balance and should depend on their energy reserves to maintain themselves. This energy stock is provided by the past food supply and ensures the momentarily resources needed for metabolic processes and maintenance (Boivin and Power, 1990; Huey et al., 2001; Arrington et al., 2002). Individuals having food content in their stomachs are supposedly gaining energy, and therefore, should be in a positive energy balance, compared to those having their stomachs empty (Huey et al., 2001). In ecological terms, the amount of energy input is paramount for foraging, maintenance, growth and mating (Nagy et al., 1984, 1999; Dunham et al., 1989). On an evolutionary perspective, diversification and species capacity to adapt are, in general, related to energy intake (Parsons, 1998).

Cnemidophorine lizards (Reeder et al., 2002; Harvey et al., 2012; Pyron et al., 2013; Goicoechea at al., 2016) are active foragers and only occur in America

(Wright, 1993; Reeder et al., 2002; Harvey et al., 2012). They are usually found in open habitats with sandy soil (Schall and Ressel, 1991, Dias and Rocha, 2007), high temperatures (Menezes and Rocha, 2011), and relatively low humidity (Pianka, 1970; Vitt et al., 1993). A study on feeding ecology of 16 populations from five cnemidophorine species along approximately 5,000 km the Brazilian coast, showed that they are omnivorous and feed mainly on insect larvae and termites (Menezes et al., in prep). These five species have different reproduction modes: four are bisexual (*Glaucomastix abaetensis, Ameivula ocellifera, Glaucomastix littoralis* and *Contomastix lacertoides*) and one is unisexual (*Ameivula nativo),* consisting only of females (Menezes et al., 2004; Menezes and Rocha, 2013).

Some assumptions can be made relating area/activity/foraging mode and frequency of individuals with empty stomach. In general, Neotropical and diurnal lizards are expected to have a lower frequency of empty stomachs in comparison to desert and nocturnal lizards, while widely foraging species have a higher frequency than sit-and-wait foragers (Huey et al., 2001). Although the study of Huey et al. (2001) included some Brazilian Amazon lizard species, there are still no studies available regarding Brazilian Atlantic Forest teiids. In the present study, we analyzed the proportion of empty stomachs in five diurnal cnemidophorine species (*G. abaetensis, A. ocellifera, A. nativo, G. littoralis,* and *C. lacertoides*) known to occur along the Brazilian eastern coast to obtain a relative estimate of their different rates of instantaneous energy balance.

2. Material and Methods

Individuals used in this study were collected along approximately 5,000 km of the Brazilian eastern coast, in 15 areas of restinga habitats. Restingas are part of the Atlantic Forest biome and can be found between the mountains and the seas of the Brazilian eastern coast. These habitats are formed by beaches and sandy dunes formed as a result of successive marine regressions which occurred during the Holocene and Pleistocene periods, during the Quaternary (Suguio and Tessler, 1984).

Fieldwork was carried out along three years (2004-2006,), during the rainy season (October-May). The only exception was for the population of Guaratiba locality, for which were used data from a one year survey available from a previous study. This population did not have diet differences between seasons, so data from the dry season was also included to expand its sample size of individuals. Lizards were collected during their activity period (09:00-16:00h) using rubber bands or pellet rifles. Being later euthanized with ether and immediately fixed in 10% formalin. Individuals were measured (snout-vent length in mm) and had their stomach contents removed and identified in the laboratory. By means of comparison, the percentage of individuals with empty stomachs was calculated for each species and population.

3. Results and Discussion

We analyzed a total of 550 cnemidophorine individuals, ranging from 23 specimens of *Glaucomastix abaetensis* to 237 specimens of *Ameivula nativo* (Table 1). Our data showed that in the studied populations the proportion of

Table 1. Percentage of individuals (N = 550) from five coastal cnemidophorines species (*Glaucomastix abaetensis, Ameivula ocellifera, Glaucomastix littoralis, Contomastix lacertoides*, and *Ameivula nativo*) having empty stomachs according to each species/population and locality, along eastern Brazilian Coast. Numbers in parenthesis indicate number of individuals having empty stomachs regarding the total number of lizards sampled from that species/population.

Species	Locality	Empty Stomachs %	Empty Males %	Empty Females %	Empty Juveniles %
Ameivula nativo	Setiba	11.1 (4/36)	-	11.1 (4/36)	0 (0/0)
5% (12/237)	Comboios	9 (3/43)	-	6.9 (3/43)	0 (0/0)
	Guriri	0 (0/35)	-	0 (0/35)	0 (0/0)
	Prado	0 (0/11)	-	0 (0/11)	0 (0/0)
	Guaratiba	2.9 (3/101)	-	2.9 (3/101)	0 (0/0)
	Maraú	9 (1/11)	-	9 (1/11)	0 (0/0)
Ameivula ocellifera	Guarajuba	2.1 (1/46)	5 (1/20)	0 (0/19)	0 (0/7)
1.7% (3/174)	Piaçabuçu	2.5 (1/40)	0 (0/16)	6.6 (1/15)	0 (0/9)
	Barra dos Coqueiros	0 (0/18)	0 (0/7)	0 (0/7)	0 (0/4)
	Genipabu	5.5 (1/18)	0 (0/3)	0 (0/3)	8.3 (1/12)
	Praia do Porto	1.9 (1/52)	0 (0/18)	3.8 (1/26)	0 (0/8)
Contomastix lacertoides 3.1% (1/32)	Joaquina	3.1 (1/32)	0 (0/19)	7.6 (1/13)	0 (0/0)
Glaucomastix abaetensis 0% (0/23)	Guarajuba	0 (0/23)	0 (0/9)	0 (0/5)	0 (0/9)
Glaucomastix littoralis	Grussaí	11.1 (3/27)	25 (2/8)	1 (1/10)	0 (0/9)
4.7% (4/84)	Jurubatiba	3.2 (1/31)	5.2(1/19)	0 (0/9)	0 (0/3)
	Maricá	0 (0/26)	0 (0/19)	0 (0/8)	0 (0/9)

Ameivula nativo is unissexual, therefore has no males.

individuals running on empty varied from 0 to 11.1% among the different species/populations of coastal cnemidophorines. The low number of lizards running on empty is suggestive of an overall positive energy balance in the 16 populations of coastal Brazilian cnemidophorine lizards studied. In fact, within these populations, five had no individuals with empty stomachs (*Ameivula nativo* in Prado and Guriri, *A. ocellifera* in Barra dos Coqueiros, *Glaucomastix abaetensis* in Guarajuba, and *G. littoralis* in Maricá), which reinforces this idea. The five species studied are considered active foragers, which generally imply high daily energy expenditure, but also high rates of prey encounter (Nagy et al., 1984; Huey et al., 2001; Teixeira-Filho et al., 2003). This can lead to lower frequencies of individuals with empty stomachs, and consequently, higher gain of energy (Nagy et al., 1984; Huey et al., 2001). Our results for Brazilian coastal cnemidophorines are similar to those obtained by Huey et al. (2001) for lizard species, in which for the Neotropical species from the Teiidae family there was an average of 12.4% individuals with empty stomachs.

The energy costs of prey capture have to be in accordance with net energy intake from prey (Schoener, 1971; Norberg, 1977). Differences in behavior, microhabitat use and/or morphological variables (Paulissen, 1987) may change food habits among sex and age-classes of predators. Our results show that the number of individuals without stomach content varied both between species and between populations (Table 1). The proportion of specimens with an empty stomach of the *A. nativo* populations, that only have females, varied similarly as the bisexual cogeneric species. This suggests that sex may not play a major role in foraging success. As there were fewer juveniles in our samples, it prevented us to estimate their relative degree of running on empty. However, out of nine populations and from a total of 70 juveniles, all of them had contents in their stomachs, except for one individual of an *A. ocellifera* population in Genipabu.

We conclude that the overall proportion of Brazilian coastal cnemidophorine lizards having empty stomachs in the five species and their populations can be considered relatively low. The frequencies of empty stomachs found in our study concur to those predicted to teiid tropical and diurnal lizards and are suggestive that the five cnemidophorine species are overall in a relatively positive energy balance.

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