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Diet of *Phrynops geoffroanus* (Schweigger 1812) (Chelidae) in an Environmental Protection Area in the Amazon Region of Maranhão State, Brazil

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***Abstract*.—The knowledge of the dietary composition of a species can identify important food resources for individuals and limiting resources for populations. We analyzed the dietary composition of Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) by collecting stomach contents between May and November 2013. We calculated the modified Index of Relative Importance (IRI) to determine which food items were the most representative for each sex and size class. We analyzed the diet of 113 *Phrynops geoffroanus* (51 males, 49 females, and 13 juveniles) based on food items classified as plant or animal (fish, amphibian, insect, gastropod, crustacean or unidentified animal material). For males, there was no significant difference in the quantity consumed between animal and plant matter ($\chi^2 = 1.376$, df = 1, $P = 0.241$), and for females there was a significant difference, with a higher consumption of animal matter ($\chi^2 = 32.85$, df = 1, $P < 0.001$). Based on the Index of Relative Importance (IRI), the food of greatest importance for juvenile categories were plants (IRI = 77.29%) and insects (IRI = 11.05%).**

Key Words.—chelonians; conservation; ecology; freshwater turtle; stomach contents

Introduction

Understanding the nutritional requirements of turtles is an important requirement of implementing in-situ and ex-situ conservation efforts (Balensiefer and Vogt 2006). Diet studies provide information about the resources that are used by turtles, and leads to knowledge of the relationships of the species with the environment and other organisms (Souza and Abe 1998). Understanding the variation of the diet in natural populations helps to identify important food resources for individuals, and identifying limiting resource for the population (Goodyear and Pianka 2011). During the lifetime of an organism, dietary changes can and do occur (Dreslik 1999). Some authors have reported the ontogenetic diet in different species of turtles, trending from carnivory as juveniles to herbivory as adults (Clark and Gibbons 1969; Georges 1982; Chessman 1984, Kennet and Tory 1996; Allanson and Georges 1999). Additionally, there are quantitative and qualitative changes in diet between different times of the year due to the seasonality of food resources (Mahmoud 1968; Parmenter and Avery 1990; Dreslik 1999; Alcalde et al. 2010).

The change from carnivory to herbivory in some adult turtles may be a result of the greater abundance of plant matter than animal matter in most freshwater aquatic systems, making this food source easily exploited. Additionally, adult turtles need lower amounts of nutrients than juveniles, as smaller animals often have to absorb animal protein rich in calcium for growth (Hart 1983). However, adult turtles still invest some time and effort to catch small quantities of animal matter, and this suggests that it is an important nutritional contribution (Bjorndal 1991). Changes in the composition of the diet commonly occur with age, sex, food availability as a function of habitat and interspecific interactions (Mahmoud and Klicka 1979; Zug et al. 2001), competition and predation (Perry and Pianka 1997), and food preferences (Zug et al. 2001).

Dietary differences between the sexes are related to the size of the animal and differences in physiological requirements (Mahmoud and Klicka 1979). A major source of calcium for aquatic turtles are food items of animal origin, particularly the aquatic larvae of insects (Ephemeroptera, Odonata, Plecoptera, Trichoptera; Moll 1990; Souza and Abe 1995, 2000; Kennet and Tory 1996; Brandão et al. 2002) as well as a wide range of items of animal origin including vertebrates and carrion. The dietary requirements of many Brazilian turtle species are lacking (Ernst and Barbour 1989;

Figure 1. Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) from the Lake of São Francisco, located in the Environmental Protection Area of Baixada Maranhense, Brazil. (Photographed by Luis Eduardo Ribeiro).

Fachin-Terán et al. 1995; Lima et al. 1997; Souza and Abe 1995, 2000). Dietary analyses have only been completed for Carvalho's Slider Turtle (*Trachemys adiutrix*; Nascimento et al. 2009) and Scorpion Mud Turtle (*Kinosternon scorpioides*; Tavares 2011) on the Curupu Island and in the region of the Pequenos Lençóis of Maranhão, Brazil (Batistella 2008).

Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*; Fig. 1) is an aquatic turtle reaching 35 cm in length and occurs from the Orinoco River Basin to the Amazon, from São Francisco to Paraná, in Colombia, Venezuela, Guianas, Brazil, Paraguay, and north of Argentina (Ernest and Barbour 1989). It inhabits rivers and lakes, low-flowing lagoons, muddy bottoms, and abundant vegetation (Ernest and Barbour 1989). Although it is common in most Brazilian rivers and also occurs frequently in urban areas, little information has been published about the life of this species in natural environments. Most available information regarding the biology and ecology of this turtle is from captive animals (Brites 2002). We studied the composition of the diet of *Phrynops geoffroanus* in the Environmental Protection Area of Baixada Maranhense with a focus on diet variations between sexes and size classes.

Materials and Methods

Study site.—We collected samples in São Francisco Lake, located in Santa Helena municipality (S02°18'56.3"N, 045°28'15.8W"), in the Environmental Protection Area of Baixada Maranhense, Brazil (Fig. 2). Habitat associated with São Francisco Lake is predominantly flat, lowlands and floodplains with vegetation of mangroves, fluvial and alluvial marine fields, and riverine forests, which are the result of seasonal flooding of the Turiaçu River. According to Costa-Neto et al. (2001/2002), there are two seasonal periods of precipitation: the rainy season from January to July, when the perennial rivers and lakes overflow flooding the fields and turning them into large shallow lakes, and from July to December, which is a period of drought when the fields are dry resulting in the growth of vegetation, mainly grasses and sedges.

Capture of animals.—Turtles were captured from June to November in 2013, out of the breeding and nesting seasons. Commercial style turtle or hoop traps and trawls 100 m long, and 2 m in height, 10–20 cm mesh, were used to capture turtles (Legler 1960; Tucker 1994; Tucker and Moll 1997; Spencer 2001). We made seven sampling trips and each trip consisted of eight traps placed at the edge of the flooded area for 10 consecutive days, and six drags were made every day with a trawl. Total sampling effort was1,680 h with the funnel-type traps and 270 h of capture effort with trawl. We placed the traps near the shore of São Francisco Lake, at an average depth of 150 cm. As the water level decreased, we repositioned the traps to always stay with that mean depth. We checked the traps every 3 h to avoid drowning animals, accumulation of fauna, and digestion of food consumed (Vogt 1980).

Measures and obtaining the stomach contents.—We determined sex of turtles based on size and coloration of animals, shape of the carapace and head size, and the pre-cloacal distance of the tail (Pritchard and Trebbau 1984; Rueda-Almonacid et al. 2007; Vogt 2008). We weighed all captured turtles using a handgrip dynamometer (± 0.1 g) and we measured the maximum length of the carapace (MLC) using a flexible tape (± 1.0 mm). We notched all animals on the marginal scutes of the carapace for identification (Cagle 1939).

We collected stomach contents through gastric lavage (Legler 1977; Balensiefer and Vogt 2006; Alcalde et al. 2010; Martins et al. 2010; Brasil et al. 2011); we first positioned turtles with the head up, the mouth open, and we placed a rubber stopper in the mouth to prevent closure during the procedure. Subsequently, we inserted a urethral probe into the stomach with a 20 ml polypropylene syringe attached to the tube. We injected a warm NaCl solution (20g NaCl to 1 L of water) as a continuous and powerful flow. The animal was then positioned with the head down and the water flow occurred until the animal regurgitated the entire stomach contents. We performed this procedure several times in succession until nothing more came out of the stomach. We released all individuals at the site of collection.

Screening and identification.—We preserved and screened stomach contents in 70% alcohol in Labohidro (Laboratory of Hydrobiology), located at the Federal University of Maranhão, Brazil. We separated the food items into categories (leaves, fruits, fish, and shellfish) and we made identifications to the lowest possible taxonomic group, given the degree of degradation of the

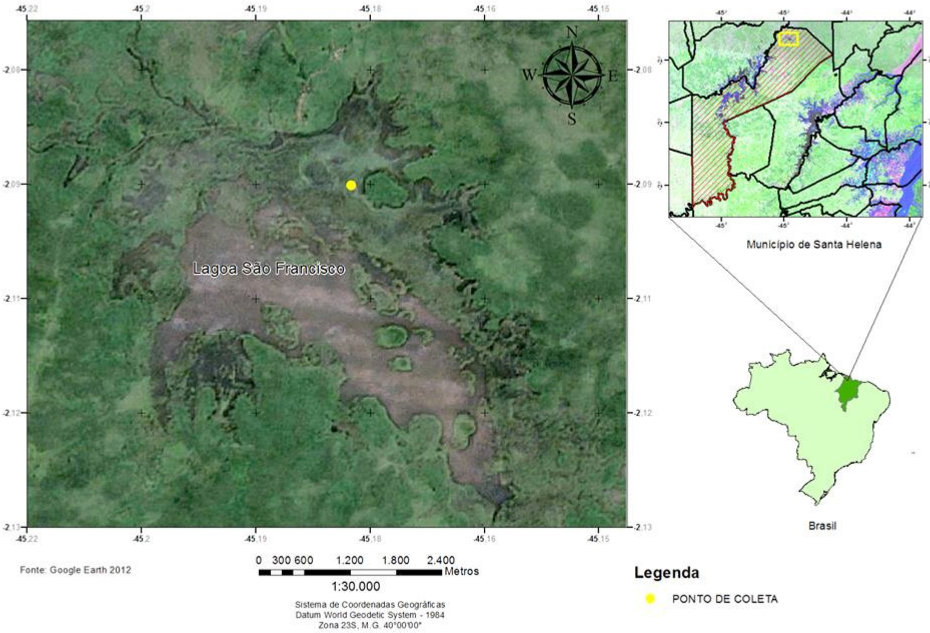

Figure 2. Map of the study area, the Lake of São Francisco, located in the Environmental Protection Area of Baixada Maranhense, Brazil.

prey in the digestive process. To analyze the quantitative variation of stomach contents, we used the volumetric method (Hyslop 1980), calculating the volume of each food item by water displacement in graduated syringes (to 0.1 ml).

Data analyses.—To determine which food items were most representative for each sex and size class, we calculated a modified Index of Relative Importance (IRI; Pinkas et al. 1971; Bjorndal et al. 1997). We calculated values based on the relative volume (V) and frequency of occurrence (FO), which is essentially the volume and the weight calculated as a percentage (Cortés 1997). The index is given by:

$$IRI = 100^* (FO^*V) / \Sigma (FO^*V)$$

To test for differences in diet based on body size, we grouped turtles into six classes of curved carapace length, with an interval of 4.9 cm from the length of the shortest individual. We placed turtles into size classes modified from Barreto et al. (2009): Class I (11–15.9 cm carapace length, CL); Class II (16–20.9 cm CL); Class III (21–25.9 cm CL); Class IV (26–30.9 cm CL); Class V (31–35.9 cm CL), and Class VI (36–40.9 cm CL). To evaluate differences in diet between sexes, we calculated a Simplified Morisita Index (Krebs 1989). The Morisita Index is calculated as

$$IM = 2\Sigma P_{ij}\, P_{ik} / \Sigma P_{ij^2} + \Sigma P_{ik^2}$$

where P_{ij} and P_{ik} are the proportions of food categories based on the values of frequency of occurrence P_{ij} (proportion of males) and P_{ik} (proportion of females). The index ranges from 0 (no similarity) to 1 (total similarity). According to Zaret and Rand (1971) and Wallace (1981), a value ≥ 0.6 indicates a significant overlap in the diets analyzed.

We compared the frequency of consumption (total volume of plant and animal matter) between the sexes using a chi-square test with 5% significance level. We used a Principal Component Analysis (PCA) to determine if there was clustering of diet types. We performed analyses with STATISTICA 6.0 software (StatSoft, Tulsa, Oklahoma, USA).

Results

We analyzed the diet of 51 male, 49 female, and 13 juvenile *Phrynops geoffroanus*. We considered individuals with a maximum length of carapace < 16 cm CL juveniles, as it was not possible to identify sex (Table 1). The average CL (± SD) of juveniles was 13.56 ± 1.53 cm and the mean weight was 215.4 ± 66.28 g. The average CL of females was 25.92 ± 6.66 cm, while for males, the average CL was 24.35 ± 4.85 cm. The average weight of females was 1,582.1 ± 1,123.4 g, while for males was 1,167.60 ± 655.71 g. We found food items in the stomachs of all sizes of turtles, which we classified as plant (although not identified further because of the degree of degradation in the digestion process) and animal. Animal contents

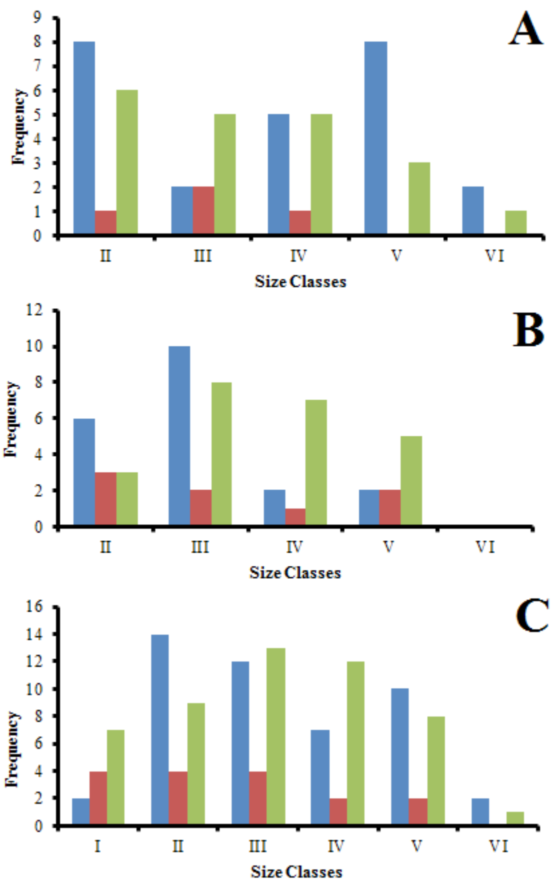

FIGURE 3. Composition of diet of Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) in the Environmental Protection Area of Baixada Maranhense, Brazil, by size class: (A) females, n = 49; (B) males, n = 51; (C) all individuals, n = 113). Categories of food items are animal (blue), plant (red), animal and plant material (green).

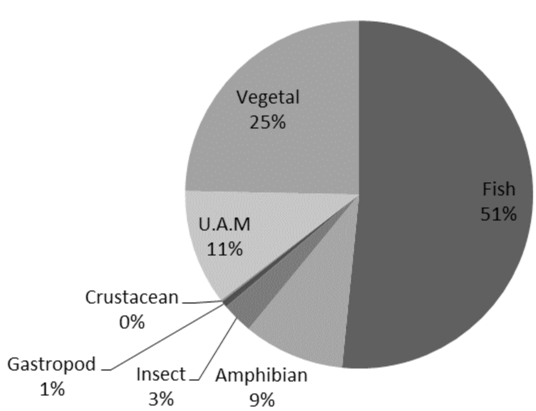

FIGURE 4. Volume of food items ingested by of Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) in the Environmental Protection Area of Baixada Maranhense, Brazil.

TABLE 1. Composition of diet of Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) in the Environmental Protection Area of Baixada Maranhense, Brazil, by size class: (A) females, n = 49; (B) males, n = 51; (C) all individuals, n = 113). Categories of food items are animal (blue), plant (red), animal and plant material (green).

Month	Female n	Male n	IndSex n	Capture method
July	13	10	-	Fyke net
August	1	8	-	Fyke net
October	15	13	7	Trawl
	12	12	6	Fyke Net
November	1	2	-	Fyke net

were fish (*Astyanax bimaculatus*, *Poptella compressa*, *Moenkhausia sanctaefilomence*, *Hoplias malabaricus*), amphibian (*Pseudis paradoxa*), insect (Odonata's pupa, Hydrophilidae, Coleoptera, Hemíptera, Neuroptera, Scarabaeidae, Curculionidae, Homoptera), the gastropod *Helix pomaceae*, crustaceans, and unidentified animal matter (UAM). In all samples, both males and females had large amounts of sediment, but due to the very small size of the particles, they were not retained by the sieve.

For females, we found that 51.02% (n = 25) consumed only animal matter; 40.81% (n = 20) consumed both plant and animal matter, and 8.16% (n = 4) consumed only plant matter (Fig. 3a). For males, 45.09% (n = 23) consumed both plant and animal matter, 39.21% (n = 20) consumed only animal matter, 15.68% (n = 8) consumed only plant matter, (Fig. 3b). For juveniles (Class I), 53.84% (n = 7) consumed both plant and animal matter, 30.76% (n = 4) consumed exclusively plant matter and 15.38% (n = 2) consumed animal matter (Fig. 3c). Of all the individuals that had an omnivorous diet (animal + plant), 61.52% were of animal origin and 38.48% of plant origin (Fig. 4).

The food category of greatest importance to juveniles was plant matter (IRI = 77.29%) followed by insects (IRI = 11.05%). For females, the food categories of greatest importance were fish (IRI = 73.71%) and plant (IRI = 14.83%). For males, the food categories of greatest importance were plant (IRI = 48.54) and fish (IRI = 40.07%). Only females consumed gastropods. Juveniles consumed the largest volume of insects (Table 2).

Juveniles (Class I) consumed a higher proportion plant matter compared to the other classes. For females in size classes II, IV, V, and VI, the predominant food item was fish (Table 2). Males in Class II consumed a majority of plant matter (IRI = 54.54%) and fish (IRI = 31.96%). The largest consumer of fish was in class III (Table 3).

There was a significant overlap in the diets consumed between males and females with a similarity degree of

Table 2. Frequency of occurrence (FO), Percentage Volume (V) and Index of Relative Importance (IRI) of the items found in the diet of Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) at the Environmental Protection Area of Baixada Maranhense, Brazil. The abbreviation UAM = unidentified animal matter. The greatest importance values are in bold type.

	Juvenile (n = 13)				Female (n = 49)				Male (n = 51)			
Categories	FO	V%	IRI	IRI%	FO	V%	IRI	IRI%	FO	V%	IRI	IRI%
Fish	7.69	43.33	333.2	8.15	46.93	61.08	2,866.9	**73.71**	47.05	41.13	1,935.5	**40.07**
Amphibian	—	—	—	—	10.2	8.16	83.33	2.15	11.76	7.63	89.84	1.85
Insect	30.76	14.66	451.4	11.05	14.28	3.04	43.44	1.11	11.76	0.97	11.4	0.25
Gastropod	—	—	—	—	8.16	1.20	9.79	0.25	—	—	—	—
Crustacean	—	—	—	—	2.04	0.16	0.32	< 0.01	1.96	0.19	0.37	< 0.01
UAM	30.76	4.66	143.54	3.51	28.57	10.8	308.8	7.95	39.21	11.45	449.0	9.29
Plant	84.61	37.33	3,158.8	**77.29**	48.97	11.76	576.34	14.83	60.78	38.58	2,345.5	**48.54**

0.95. There was not a significant difference in the diet of males and females ($\chi^2 = 1.139$, df = 1, $P = 0.286$). There was a significant difference in the frequency of food consumed: males consumed more plant matter than females ($\chi^2 = 5.974$, df = 1, $P = 0.015$) and females consumed more animal matter than males ($\chi^2 = 4.834$, df = 1, $P = 0.028$). Among males there was no significant difference in the quantity consumed of animal and plant ($\chi^2 = 1.376$, df = 1, $P = 0.241$), while among females there was a significant difference with more animal matter consumed than plant material ($\chi^2 = 32.85$, df = 1, $P < 0.001$). Diets did not diverge with a grouping of items consumed and explained 94.1% of the original data (Fig. 5).

Discussion

Some stomach contents *P. geoffroanus* studied contained whole prey. The occurrence of whole prey is indicative of suction feeding, which consists in an oropharyngeal negative pressure caused by expansion of the volume of the oral cavity. This strategy, coupled with a rapid movement of the head toward the prey, allows for active predation by freshwater turtles, compensating for little flexibility due to the body weight (Molina 1990; Aerts et al. 2001; Lemmel et al. 2002). The diets of males and females were generally the same, although we did not find gastropods in male stomachs. The slight difference in diet may be due to size differences between the sexes: male *P. geoffroanus* are significantly smaller than females (Decant 2012). Larger turtles usually explore deeper waters, while smaller ones use shallower water (Pough 1973, 1983; Wilson and Lee 1974; Mahmoud and Klicka 1979). However, gastropods may not be a preferred food in the diet of *P. geoffroanus*, which may explain the low frequency in the diet of both sexes (Souza and Abe 2000; Dias and Souza 2005; Martins et al. 2010).

Although omnivorous, juveniles consumed a large amount of plant matter at our site. According to Fachin-Teran et al. (1995), plant matter is considered important in the diet of *P. geoffroanus* and females had a predominantly carnivorous diet, mostly fish, whereas males had an omnivorous diet, feeding on both plant and animal matter. Other studies suggest that the species is almost exclusively carnivorous, with plant consumption an accidental event (Medem 1960; Molina 1989, 1990; Souza and Abe 2000). Male *Podocnemis vogli* in Venezuela feed mainly on plant matter, while females feed more on mollusks and fish, and this difference may be due to the calcium needs of females for forming eggs (Ramo 1982). Female *Trachemys adiutrix* in the state

Table 3. Index of Relative Importance (IRI) of items found in the diet of male and female of Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) by size classes (see Methods) in the Environmental Protection Area of Baixada Maranhense, Brazil. The abbreviation UAM = unidentified animal matter. The greatest importance values are in bold type.

	Males (n = 51)				Females (n = 49)				
Food Category	Class II	Class III	Class IV	Class V	Class II	Class III	Class IV	Class V	Class VI
Fish	**31.96**	**56.70**	17.29	16.27	**72.73**	**31.77**	**74.39**	**47.66**	**93.27**
Amphibian	—	0.60	2.09	—	—	—	11.73	19.06	—
Gastropod	—	—	—	—	2.09	—	0.14	—	—
Insect	—	0.16	0.26	0.15	9.76	0.40	—	0.20	—
Crustacean	—	0.96	0.08	—	0.13	—	—	—	—
UAM	13.49	16.83	2.44	6.82	2.09	12.22	7.163	8.11	5.76
Plant	**54.54**	24.73	**77.81**	**76.74**	13.17	**55.60**	6.55	**24.94**	0.96

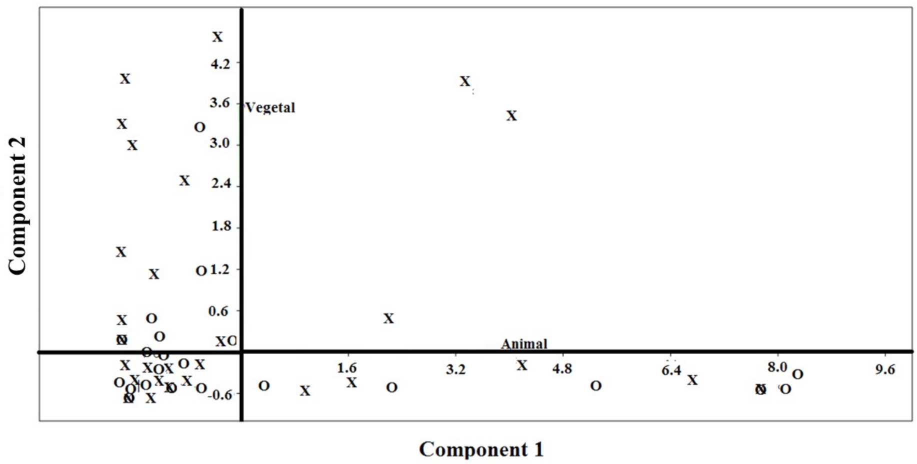

Figure 5. Principal Component Analysis - PCA (x = animal matter; o = plant matter) of Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) in the Environmental Protection Area of Baixada Maranhense.

of Maranhão feed more on plant matter, while males feed most on animal (Nascimento et al. 2009). Juvenile animals were considered omnivorous, consuming as much fish as the plant matter. Adult animals consumed more animal than plant matters. Our data suggests that, overall, this population of *P. geoffroanus* tends to have an omnivorous diet.

Although there is a difference in the food contents in the size classes, we did not observe a change in diet related to the size of the individuals. Teran et al. (1995) observed an increase in the consumption of seeds and fruits in *Podocnemis unifilis* that was correlated to the size of the animals. They also found differences in food preferences between males and females. In another study conducted in captivity with *Trachemys scripta*, Bouchard and Bjorndal (2006) found that species of juvenile turtles can process plant matter, while a diet high in animal matter allowed a more rapid growth rate, which in turn was related to greater survival rates and increased future reproductive success.

Phrynops geoffroanus is important in the food web of water ecosystems where it occurs, playing important roles in vital functions such as energy flow, nutrient cycling, dispersal of riparian vegetation and maintenance of water quality and high densities of biomass (Moll and Moll 2004). The integrity of this ecosystem is essential for vital activities of the species. The detailed information about the diet of this turtle is important to any effort aimed at conservation because it is directly attached to food availability, allowing appropriate decisions by managers to the population in the Environmental Protection Area of Baixada Maranhense.

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