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Dietary variation and overlap in D'Orbigny's slider turtles *Trachemys dorbigni* (Duméril and Bibron 1835) (Testudines: Emydidae)

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Although D'Orbigny's slider (*Trachemys dorbigni*) is the most abundant freshwater chelonian species in southern Brazil, little is known about its feeding habits. Our goal was therefore to evaluate this species' dietary composition and niche variation there. For this, we collected road-killed animals (n = 73) on a federal highway (BR 392) between 2002 and 2003, and analysed their gut contents. We identified 26 different dietary items, and our results indicated that D'Orbigny's slider is omnivorous in this area. Total food volume, as well as the degree of herbivory and carnivory, were similar between males and females. However dietary composition of plants was different: although both males and females fed on underwater plant matter, only females consumed surface macrophytes. This finding suggested differential microhabitat usage between males and females throughout the swamps.

Keywords: chelonian; testudines; emydidae; herbivory; carnivory

Introduction

Given the current extent of ecosystem degradation, effective conservation plans require accurate understanding of biological and ecological wildlife characteristics. In this context, feeding ecology is one of the most important issues because diet may reflect microhabitat demands and interactions with other species. For neotropical reptiles only limited dietary information is available, including for turtles and caimans in the Amazon Basin (Ossa et al. 2011; Laverty and Dobson 2013), and freshwater *Hydromedusa* and *Phrynops* turtle species (Souza and Abe 2000; Bonino et al. 2009; Alcalde et al. 2010; Martins et al. 2010). These studies revealed wide dietary variation, including carnivory, herbivory and omnivory, as well as differences by age, gender and population (Lindeman 2000; Stephens and Wiens 2003; Luiselli et al. 2004; Bonino et al. 2009; Alcalde et al. 2010). However specialists recognize the lack of information available on the conservation status of freshwater turtles in southern Brazil.

Trachemys dorbigni (D'Orbigny's slider) is the most abundant freshwater turtle in southern Brazil, occurring also in Argentina and Uruguay (Pereira and Diefenbach 2001). Adults of this species have maximum carapace lengths of > 130 mm and maximum plastron lengths of > 110 mm, with females being ~ 16% larger than males (Bager et al. 2010). In southern Brazil females can travel up to ~ 500 m during the nesting period and tend to display fidelity to their nesting sites (Bager et al. 2012).

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This species is the second most common reptile in the Brazilian wild animal trade and is threatened by the exotic red-eared slider *Trachemys scripta* (Bager et al. 2007; Bujes and Verrastro 2008). Further, D'Orbigny's slider habitat is under constant threat of fragmentation (Bujes 2010).

There are few studies available concerning the diet of D'Orbigny's sliders. In captivity, the species has demonstrated omnivorous and generalist tendencies (Lema and Ferreira 1990; Molina 1997). The same pattern may be found in nature (Cabrera 1998), although predominately carnivorous habits were identified in Argentina (Gallardo 1977). Bujes et al. (2007) identified the exotic golden mussel *Limnoperna fortunei* in this turtle's diet and suggested that D'Orbigny's sliders are opportunistic. However, all of these studies are descriptive and none identified consistent dietary patterns. Further, there are still gaps concerning dietary description, niche subdivision and dietary variation related to gender and individual size in natural populations in southern Brazil. Bridging these gaps is very important in light of the threats to this species, and our goals were therefore to: (1) determine the composition and importance of feeding categories in the diet of wild D'Orbigny's slider adults in southern Brazil; and (2) evaluate differences in diet between males and females.

Material and methods

We collected road-killed individuals on a federal highway (BR 392) in southern Brazil (Figure 1) during the species' nesting season (Bager et al. 2007; Fagundes et al. 2010) from October 2002 to January 2003. This area is located on the shores of the São Gonçalo Canal (31°45′43″ N, 52°21′00″ W). We transported the specimens to the laboratory where we measured them using callipers accurate to 1 mm, identified their sex, and removed the digestive tract.

The biometric measurements taken were: maximum carapace length (MCL) and maximum plastron length (MPL). Individuals with MCL > 130 mm or MPL > 110 mm were considered adults, following Bager et al. (2010). Due to massive injuries caused by collisions with cars and trucks we restricted biometric measurements to animals that could be measured, regardless of their stomach content. We fixed the digestive tract in 10% formalin and later preserved it in 70% alcohol until the stomach contents were assessed. We examined food items under a stereomicroscope and identified them to the lowest possible taxonomic level.

We calculated the volume of each food item through the displacement of water in a graduated syringe. The analyses of the food items included total percentage volume ([total number of an item]/[total number of all items] × 100, for each individual) and frequency of occurrence (percentage of turtles in which a food item was found) (Carrión-Cortez et al. 2010). Then we compared the number of food items consumed by males and females through rarefaction analyses, with 10,000 iterations, using the ECOSIM program (Gotelli and Entsminger 2004). Only those animals with known genders were analysed.

We classified the food into 11 items: algae (AL), surface macrophytes (SM), bottom macrophytes (BM), unidentified macrophytes (UM), plant remains (PR), gastropods (GA), crustaceans (CR), insects (IN), vertebrates (VE), others (OT) and unidentified (UN). We grouped spiders, dust mites, and leaches in "others" (OT), because they represented < 0.1% of the total diet volume. The PR group included decaying plants from swamp bottoms. We did not find any items in advanced

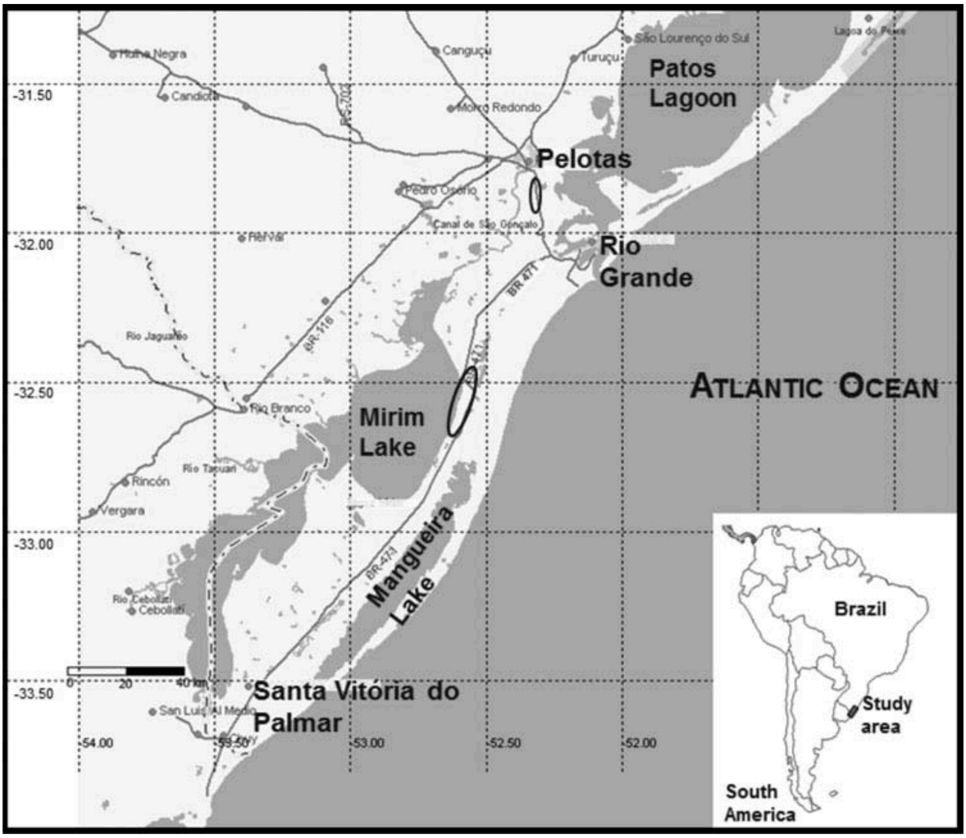

Figure 1. Study area showing the approximate location where samples were collected (black ellipsis) in Rio Grande do Sul, southern Brazil.

digestive states, which facilitated differentiation between aquatic macrophytes and decaying swamp vegetation. We classified sand and mud as sediments and removed these non-food items from the analysis.

We applied the chi-square test to determine differences in the variety of food items consumed by gender. In addition, we performed a residue analysis to evaluate how different food items contributed to the chi-square test results (Callegari-Jacques 2003). We analysed the degree of herbivory and carnivory between genders through a Mann–Whitney non-parametric U-test, using the total volume of plant and animal matter. We used non-parametric tests because the Kolmogorov–Smirnov test indicated the data were not normally distributed (Sokal and Rohlf 1995).

We estimated the importance of each item through a semi-quantitative scale of abundance, comparing the volume of each item to the total volume of stomach items. The categories on the scale proposed by Granado-Lorencio and Garcia-Novo (1986) are 0, absent; 1, scarce (< 25%); 2, frequent (25% to <50%); 3, very frequent (50% to < 75%); and 4, abundant (75–100%). Following this scale, we calculated the Food Importance Index (IIA):

$$IIA = \sum[(X_K * K)/(n-1)]$$

Where X_K corresponds to the frequency of occurrence of a specific item in the diet, X_i; K corresponds to categories on the scale of the item (0, 1, 2, 3 and 4); and n corresponds to the number of categories on the scale. According to Guillen and Granado (1984), items presenting IIA values over 0.3 are considered as the primary food; from 0.15 to 0.3 as additional food, and lower than 0.15 as accidental food.

Results

Of the 73 individuals collected, 39 (56.2%) had stomach contents. Among these, six were males, 27 were females, and six were of unknown sex. Average MCL for females (n = 13) was 212.4 ± 14.5 mm (183–233 mm) and average MPL (n = 20) was 189± 26 mm (126–227 mm). For males, the average MCL (n = 3) was 186 ± 30.4 mm (140–203 mm) and MPL (N = 11) was 168.4 mm ± 20.2 (125–186 mm).

We identified 26 different items in this slider's diet. Females fed on a greater number of different items (n = 24) than males (n = 9) (Table 1). According to rarefaction analyses the number of items consumed by the six males was lower than that estimated for the same number of females (n = 13.6 ± 2.6). While females consumed invertebrates from 16 different taxonomic units, males only consumed gastropods, hirudinea (leeches) and diptera. Among plant items, only females consumed pond scum (*Spyrogyra* sp., pondweed *Potamogeton* sp., mayaca *Mayaca* sp. and Ciperaceae), whereas only males consumed Brazilian elodea *Egeria densa* (Table 1).

Plant matter represented 85.3% of the total food volume (84.3% in females and 92.1% in males), of which 55.9% consisted of aquatic macrophytes, 24.2% of filamentous algae (genus *Spirogyra*), and 5.2% of plant remains. We found food items of vegetal origin in 85.2% of female stomach contents and in 66.7% of male stomach contents. The SM and AL categories had a higher volume percentage in females (42.7% and 30.2%, respectively), with a frequency of 29.6% and 14.8%, respectively. SM and BM had a frequency of 33.3% each and volume of < 2% for SM and 80% for BM.

Among animal items we identified molluscs, crustaceans, arthropods, hirudineans and vertebrates. These items represented 16.4% of the total volume of items in females, and 8.3% in males, having occurred in 85.2% of female contents and 50% of male contents. IN was the most frequent animal food category in males (50%), representing a volume of 0.3%. Among females, CR was the most frequent, 48.2%, representing a volume of 6.4%.

We found a significant difference in the composition of female and male diets (χ^2 = 74.8; gl = 9; p < 0.01). According to the residue analysis, the food items that contributed to this difference were, in order of importance: AL, SM, PR, GA, CR, IN and OT. We did not find differences in female diets among sampling years/seasons (2002–2003) (χ^2 = 3.2; gl = 8; p > 0.1). The degrees of herbivory (U = 77,000; p = 0.98) and carnivory (U = 71,000; p = 0.76) were the same for males and females. Regarding food importance, the PR category represented the main food for females, while SM, GA, CR and IN were considered additional food. For males, BM and UM were considered primary foods, and IN and GA as additional foods (Table 2).

Table 1. Total percentage of volume (PV) and frequency of occurrence (FO) of food items in *Trachemys dorbigni* females and males of southern Brazil.

	Males		Females	
Food item	PV	FO	PV	FO
Clorophyceae (Algae)				
Spirogyra sp.	0	0	24.53	14.81
MACROPHYTE				
Salvinea sp.	5.49	16.67	35.74	37.04
Ciperacea	0	0	0.1	3.7
Potamogeton sp.	0	0	15.55	7.41
Mayaca sp.	0	0	0.46	7.41
Egeria densa	7.13	16.67	0	0
Plant remains	38.4	33.33	9.74	51.85
GASTROPODA	5.48	16.67	2.81	29.63
HIRUDINAE	0.07	16.67	0.06	3.7
ARACHNIDA				
Acari	0	0	0.03	7.41
Aranae	0	0	0.003	3.7
CRUSTACEA				
Copepoda	0	0	0.22	29.63
Cladocera	0	0	4.89	33.33
Ostracoda	0	0	0.08	14.81
Amphipod (*Hyallela*)	0	0	0.12	18.52
INSECTA				
Unidentified insects	0.24	33.33	0.34	33.33
Diptera	0.22	16.67	0.08	18.52
Hemiptera	0	0	2.95	25.93
Odonata	0	0	0.008	3.7
Hymenoptera	0	0	0.24	3.7
Coleoptera	0	0	0.06	14.81
Plecoptera	0	0	0.0005	3.7
Neuroptera	0	0	0.001	3.7
VERTEBRATA				
Anuran	0	0	1.14	3.7
Characiformes	7.68	16.67	0	0
Others	35.29	83.33	0.86	70.37

Table 2. Food importance index estimates for the food items identified in the *Trachemys dorbigni* diet.

	AL	SM	BM	UM	PR	GASTR	CRUST	IN	VERT	OUT
Females	0.12[c]	0.26[b]	0.01[c]	0.05[c]	0.31[a]	0.17[b]	0.25[b]	0.16[b]	0.02[c]	0.04[c]
Males	0.00[c]	0.08[c]	0.33[a]	0.33[a]	0.00[c]	0.17[b]	0.00[c]	0.25[b]	0.04[c]	0.04[c]

Notes: Abbreviations are as follows: AL, algae; SM, surface macrophytes; BM, bottom macrophytes; UM, unidentified macrophytes; PR, plant remains; GASTR, gastropods; CRUST, crustaceans; IN, insects; VERT, vertebrates; OUT, others; UN, unidentified.
[a]Main food, [b]additional food, [c]accidental food.

Discussion

Our results indicate that D'Orbigny's slider is an opportunistic omnivore that consumes a great diversity of plant and animal items at our study site. Cabrera (1998) noted the same pattern in Argentina, and Bujes et al. (2007) observed in Brazil individuals feeding on invasive golden mussels in nature. Studies in captivity have also suggested opportunistic feeding behaviours in this slider (Lema and Ferreira 1990; Molina 1997). Other species of slider turtles have been recognized as opportunistic omnivores, including subspecies of the red-eared slider that feed on a wide variety of aquatic vegetation and animal items (Clark and Gibbons 1969; Moll and Legler 1971; Parmenter 1980; Hart 1983; Pritchard and Trebbau 1984; Moll 1990; Parmenter and Avery 1990). This similarity may indicate a related and similar foraging strategy among Emydidae species, as was observed in Pelomedusidae (Pérez-Éman and Paolillo 1997).

Bonino et al. (2009) suggest that differences between genders in degree of carnivory and herbivory are common in certain chelonian species. However, the differences we found in the dietary composition of males versus females are probably due to ingestion of plant items rather than differential carnivory. Sliders have ontogenetic and sexual differences in feeding behaviour: juveniles are more insectivorous than adults, and females are more herbivorous than males (Hart 1983; Moll 1990; Parmenter and Avery 1990; Lagueux et al. 1995; Teran et al. 1995). These differences could be related to the size differences between males and females (Plummer and Farrar 1981; Vogt 1981). However, we found that both males and females fed on underwater plant matter, but only females consumed surface macrophytes. Further, females ate invertebrates more frequently than males did. These differences suggest different microhabitat usage throughout the swamps between males and females, although the number of males in our sample may be limiting our conclusions. Differences in feeding habits (or the division of food resources) reduce competition and presumably enable coexistence between individuals of the same species (Souza and Abe 2006; Bonino et al. 2009).

Moll and Legler (1971) noted that chelonian females foraged on alternative resources during the reproductive season to obtain energy for egg production and laying. However, some turtles do not eat during the nesting season. Because this study was carried out during this period and most females had stomach contents, we hypothesize that the D'Orbigny's slider does feed during the nesting season in southern Brazil. We strongly recommend further studies of this species' diet, including additional seasonal cycles and a higher number of males. Evaluating whether sample sizes or seasonality have affected niche overlap and variation, as well as diet composition of the D'Orbigny's slider, should be considered a high research priority.

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