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Diet of *Philodryas olfersii* (Serpentes, Colubridae) during hydroelectric dam flooding in southern Brazil

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Abstract. We describe aspects of the feeding ecology of a population of the colubrid snake *Philodryas olfersii* in central Rio Grande do Sul State, Brazil. Based on specimens obtained during the fauna rescue operation of Dona Francisca hydroelectric powerplant, we conducted the first analysis of the diet of a snake during artificial flooding of an area in Brazil. Females attained larger body sizes than males, and ingested heavier prey. We observed a high proportion of recently-fed individuals; mammals were the most frequent prey, followed by birds and frogs. Our results differ drastically from those obtained for *P. olfersii* in adjacent areas. The frequency of items and dominance of major prey categories in the diet of this snake seem to have been influenced by an unusual exposure of rodents and, consequently, changes in prey detectability resulting from the dam flooding.

Key words: dietary shift, feeding, *Philodryas*, Rio Grande do Sul, river damming

Introduction

Studies on the effects of profound environmental alterations such as river damming and the formation of reservoirs on the herpetofauna are only beginning in Brazil (Rodrigues 1999, Alho et al. 2003, Brandão & Araújo 2008). Flooding drastically impacts faunal elements, whose responses are associated with their life modes, specializations and displacement capacity (Cosson et al. 1999, Marinho-Filho 1999). Dam flooding presents a unique opportunity to collect information in order to evaluate those impacts on distinct animal groups (Vasconcelos 1999), and consequently to assess the efficiency of conservation practices adopted by the energy sector (Marinho-Filho 1999).

Feeding, including quantitative, qualitative and behavioral aspects, is an important ecological characteristic in the natural history of snakes. Much valuable information on snake ecology can be obtained by examining the digestive tracts of preserved specimens in scientific collections (Shine 1988, 1989, Michaud & Dixon 1989).

Philodryas olfersii (Lichtenstein 1823) is a medium-sized colubrid snake widely distributed throughout South America, occurring in western Brazil, eastern Peru, Bolivia, Paraguay, Uruguay and Argentina (Peters & Orejas-Miranda 1970). This species displays semi arboreal habits, living in forests

and neighboring areas (Sazima & Haddad 1992, Cechin 1999, Hartmann & Marques 2005). A generalist predator, *P. olfersii* can prey on a wide variety of small vertebrates (Vitt 1980, Lema et al. 1983, Sazima & Haddad 1992, Rocha & Vrcibradic 1998, Hartmann & Marques 2005).

We studied the diet of *P. olfersii* through the analysis of individuals rescued during the flooding caused by a new hydroelectric dam in the central region of the state of Rio Grande do Sul, Brazil. We compared our results with a previous study on the diet of the same species, also in central Rio Grande do Sul (Hartmann & Marques 2005). The objective was to evaluate whether aspects of the feeding biology of this snake were affected by the flooding of the study area on the occasion of the formation of the reservoir.

Material and Methods

Dona Francisca hydroelectric power plant is located in the final stretch of the middle Jacuí River, between the cities of Agudo and Nova Palma, state of Rio Grande do Sul, Brazil. The dam is located at 29°26'50''S and 53°16'50''W, and the reservoir covers a total area of 1,337 ha. The study area lies in the transition zone between the physiographic provinces of the Encosta Inferior do Nordeste and Depressão Central, where the relief ranges from steeply mountainous to a slightly rolling plain. According to Klein (1984), the predominant vegetation is seasonal deciduous forest. The mentioned physiographic provinces are the same from which preserved specimens of *P. olfersii* studied by Hartmann & Marques (2005) were collected. Mean temperature is 18°C and mean annual rainfall is 2000 mm. Mean annual air relative humidity is 87%, peaking in the winter months (Companhia Estadual de Energia Elétrica, as cited in Kaefer et al. 2007).

The scientific utilization of particular animal groups rescued from artificially flooded areas is recommended given that the translocation of individuals can cause numerous negative effects on the release target areas such as those related to genetic structure of populations and environmental carrying capacity (*for discussion see* Marinho-Filho 1999 *and* Rodrigues 1999). We examined 68 preserved specimens of *P. olfersii* collected during a faunal rescue operation from 08 to 16 November 2000, when the flooding of the reservoir of Dona Francisca Hydroelectric Dam took place. Specimens are housed in the collection of the Universidade Federal de Santa Maria (ZUFSM). We recorded snout-vent length (SVL), tail length (TL) (both in millimeters) and weight (to the nearest 0.1g) of the individuals. We assessed sexual maturity through gonad examination (see criteria in Shine 1977).

To assess sexual dimorphism, we considered the differences between snout-vent length (SVL) of both sexes. The mean size of the larger sex relative to the smaller was used to assess the degree of sexual dimorphism in SVL. The difference between the obtained value and 1.0 was used as an index of sexual dimorphism (see Gibbons & Lovich 1990).

The digestive tract of each specimen was dissected to examine gut contents, number of prey types, and prey orientation during ingestion. Prey items were identified to the level of order, and were weighed to the nearest 0.1g. In order to evaluate prey availability in the study area, data on abundance of rodents and anurans recorded during the fauna rescue operation were obtained from the Relatório de Resgate da Fauna da Usina Hidrelétrica Dona Francisca (unpubl.). These data were collected during the flooding of the reservoir by active search through the lake and its margins using boat and terrestrial transects. Given that most of the mature birds are capable to escape from flooded areas, data on the abundance of recorded/rescued Passeriformes were not considered in this study.

Statistical analyses were performed using the program BioEstat 4.0 (Ayres et al. 2005). Sexual dimorphism in SVL was assessed by Student's t test, and in TL by analysis of covariance (ANCOVA) using SVL as covariate. The Mann-Whitney test was employed to test if there was a difference between males and females regarding the weight of ingested prey items. We assessed the relationship between snake weight and each prey weight through Pearson's linear correlation. For all analyses, significant results were considered when $P < 0.05$ (Zar, 1996).

Results

Among the 68 individuals collected in the study area, 39 (57.3%) were females and 29 (42.6%) were males. Thirty-four of the females (87.1%) were mature, as were 28 (96.5%) of the males.

SVL ranged from 698 to 1015 mm (mean = 833.0, SD = 70.3, n = 34) in mature females, and from 522 to 774 mm (mean = 664.0, SD = 68.4, n = 28) in mature males. Tail length averaged 319.1 mm (SD = 33.2, range = 170-374, n = 34) in adult females, and 294.6 mm (SD = 31.0, range = 245-362, n = 28), in adult males. Females were larger in SVL ($t = 9.52$, $df = 60$, $p < 0.001$), but relative tail length was not statistically different between sexes (ANCOVA, $F = 3.80$, $p = 0.055$, $n = 62$). The SVL sexual size dimorphism index was 0.25.

Forty-five individuals (66.2% of the sample) had 47 items as gut content. Among the 29 males analyzed, 23 (79.3%) had 25 items, while 22 (56.4%) of 39 females analyzed had 22 food items in the stomach and intestine.

The mean weight of the food items was greater in females ($U = 4.5$, $Z = 3.17$, $p = 0.0014$, $n = 18$) (Figure 1). However, there was no significant correlation between prey weight and the body weight of females ($t = 2.06$, $r = 0.61$, $p = 0.077$, $n = 9$) or males ($t = -0.38$, $r = -0.14$, $p = 0.708$, $n = 9$). Most of the prey (n = 20, 71.4%) were ingested headfirst.

In the diet of *P. olfersii*, we recorded prey items belonging to the orders Rodentia (n = 29, 61.7%), Passeriformes (n = 6, 12.8%), and Anura (n = 2, 4.2%) (see Table 1 for the data, arranged by snakes' sex). We were unable to identify 10 of the 47 items. In two males, we

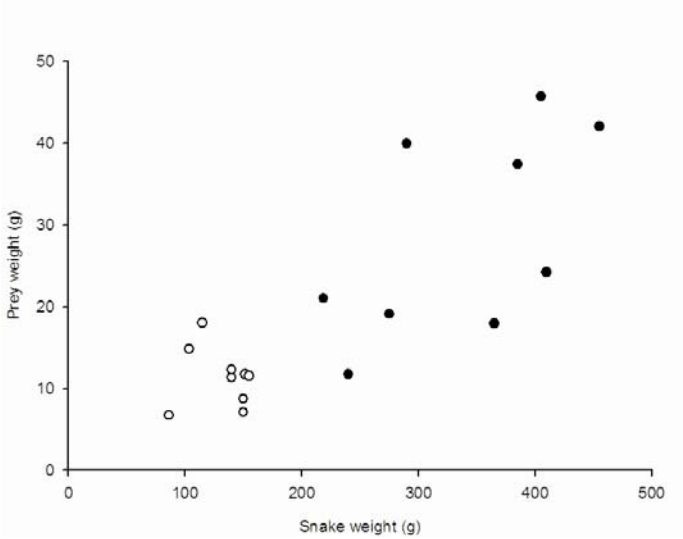

Figure 1. Relationship between ingested prey weight and the weights of nine male (open circles) and nine female (closed circles) specimens of *Philodryas olfersii* in central Rio Grande do Sul, Brazil.

Table 1. Categories of prey ingested by 25 male and 22 female specimens of *Philodryas olfersii* in central Rio Grande do Sul, Brazil.

	Males		Females		Items (Total)	
Prey category	N	%	N	%	N	%
Anura	2	8	0	0	2	4.2
Passeriformes	2	8	4	18.2	6	12.8
Rodentia	15	60	14	63.6	29	61.7
Not identified	6	24	4	18.2	10	21.3
Total	25	100	22	100	47	100

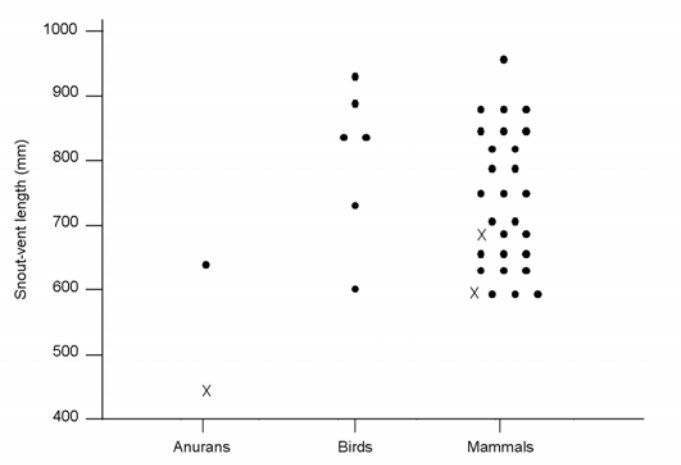

Figure 2. Categories of ingested prey in relation to snout-vent length of 34 mature (circles) and 3 juvenile (X's) *Philodryas olfersii* from central Rio Grande do Sul, Brazil

found two food items: a bird and a rodent in one (ZUFSM 2178), and two rodents in the other (ZUFSM 0397). Altough ectothermic prey was ingested only by smaller individuals (Figure 2), the low number (n = 3) of recently-fed juveniles in our sample do not allow us to state that a diet shift occurred with increasing body weight. During the faunal rescue operation, 235 amphibians and 348 rodents were recorded in the study area.

Discussion

In Brazil, there are many studies on the diet of snakes under natural circumstances (e.g., Vitt 1980, Andrade & Silvano 1996, Marques

& Sazima 1997, Oliveira et al. 2001, Pinto & Lema 2002, Leite et al. 2007, Marques & Muriel 2007). However, as far as we know, there are no descriptions of the feeding of snakes in artificially flooded areas.

The segregation of prey between males and females observed in the present study, in which females took heavier prey than males, probably results from the larger mean size of females recorded in this study and previously (Vitt 1980, Hartmann & Marques 2005). However, we highlight that the positive relationship between female weigh and prey weigh was only marginally significant. The larger body size in females observed in this population of *P. olfersii* is in agreement with the observations by Hartmann & Marques (2005). The SVL sexual dimorphism index (0.31) obtained by those authors is also close to the value estimated in our study (0.25). In most species of snakes, including xenodontines, females are larger than males. This characteristic is probably related to fecundity, which in females is dependent on body size (Shine 1993). The larger relative tail length in *P. olfersii* males observed by Hartmann & Marques (2005) was not corroborated by a statistically significant p value ($p = 0.055$) in our analysis. This may be due either to our smaller sample size or by differences in data analysis, given that we used ANCOVA to control for body size effects as recommended by García-Berthou (2001).

A predominance of prey items ingested headfirst is reported for ophiophagus snakes (Greene 1976, Marques & Sazima 1997), but also for xenodontine snakes that feed on rodents, such as *Oxyrhopus guibei* and *Clelia rustica*, probably to avoid injury during the swallowing process (Andrade & Silvano 1996, Pinto & Lema 2002).

The high proportion of recently-fed individuals in our sample (66.2%), in comparison with data available for *P. olfersii* in nearby areas (32%, Hartmann & Marques 2005), probably reflects an increased detectability of prey by *P. olfersii* in the period when the specimens were captured, caused by the flooding of the area. During the period of reservoir formation and fauna rescue, a representative number of rodents in comparison to frogs ($n = 348$ and $n = 235$, respectively) was reported. This apparent high detectability by unusual exposure of prey, including rodents on the water surface and on partly submerged branches (S. Cechin, Santa Maria, pers. comm. 2008), likely made them more vulnerable to *P. olfersii*.

In the Caatinga from Northeastern Brazil, this snake feeds on small mammals and frogs, but preferably on rodents (Vitt 1980). However, in Southern Brazil, Hartmann & Marques (2005) reported that anurans were most frequently consumed (46.9%), with a smaller proportion of mammals in the diet of *P. olfersii* (23.5%). We found an inverse situation, with a predominance of rodents (61.7%), followed by birds (12.8%) and a smaller proportion of anurans (4.2%). Shine et al. (1998) noted that species with wide geographic distributions may display wide heterogeneity in food habits. Our observations agree with those of Cechin (1999), Vitt (1980), Vitt & Vangilder (1983), Lema et al. (1983) and Hartmann & Marques (2005) in relation to the composition of the major prey categories consumed by this generalist snake, but diverge in relation to their relative frequency and dominance.

One could argue that the brief period in which the specimens were collected might be one of the causes of the alteration in frequency of the *P. olfersii* food items re-

corded by this study, because the dietary composition of snakes is probably influenced by seasonal fluctuations in prey availability (see Capizzi et al. 1995). However, the collections were made during spring, when anurans are most abundant (Both et al. 2008), and probably more available to snakes. Also, Hartmann & Marques (2005) reported that anurans were the dominant prey category in the diet of *P. olfersii*, independently of the time of year. Therefore, the collection period does not explain the low occurrence of anurans in the diet of *P. olfersii*, as recorded in the present study.

The low proportion of juvenile individuals of *P. olfersii* in our sample (8.8%) may also be one of the causes of the observed pattern, given that other studies detected a diet shift with increasing body size (Shine 1994, Hartmann & Marques 2005), where juveniles of this species fed on ectothermal prey. However, while similar proportions of juvenile individuals were found in the study by Hartmann & Marques (2005), their results indicated a general dominance of anurans in the diet.

The small proportion of birds found in this study was also observed for the arboreal colubrid *Thelotornis capensis*, in Australia (Shine et al. 1996). These results reinforce Shine's (1983) prediction that detailed studies do not support a high incidence of bird predation even in fully arboreal snakes, probably because birds are difficult to capture.

Our results demonstrate that frequency and dominance of the prey items are among the aspects of the feeding biology of *P. olfersii* that mostly differed from a previous study in the same region. These changes seem to be closely related to the increased detectability of rodents caused by the flooding of the area during the period of collection of the specimens. The hypothesis that the use of environment by snakes is mainly related to the distribution and abundance of their prey (Vitt & Vangilder 1983, Bernarde & Kokubum 1999) makes the occurrence of rodents as a major food prey category in the diet of the semi-arboreal *P. olfersii* exceptional in the study area when compared with the report of Hartmann & Marques (2005). Therefore, we believe that the flooding of the terrestrial habitats made possible more encounters between *P. olfersii* and this less-usual prey. This represented a higher caloric intake in relation to predation of anurans, as expected by optimal foraging theory (McArthur & Pianka 1966, Begon et al. 2006).

Because field data indicate that the prey used by *P. olfersii* do not constitute limited resources (Cechin 1999, Hartmann 2001), we suggest that the predominance of anurans in the diet of this snake reported by Hartmann & Marques (2005) does not necessarily represent the feeding preference of this species, but merely reflects the greater availability of anurans in natural environments of southern Brazil. In addition, we hypothesize that the low percentage of anurans as gut contents recorded in this study was caused by the rapid decline in their abundance during the flooding, which was observed in the study area (S. Cechin, Santa Maria, pers. comm. 2008), and was also reported by Brandão & Araújo (2008) for the Serra da Mesa hydroelectric dam flooding in central Brazil.

We expect that our report will stimulate more-detailed and comprehensive studies involving the natural history of species affected by reservoir flooding. The growing expansion of the hydroelectric sector in Brazil (Goldemberg & Lucon 2007) should

be accompanied by more complete evaluations, not only in relation to the impacts of dam construction on the faunistic composition of affected areas (see Brandão & Araújo 2008), but also on aspects of the natural history of local animal populations.

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