Diet of the Yellow Armadillo, *Euphractus sexcinctus*, in South-Central Brazil

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Introduction
The 21 species of armadillos (Dasypodidae, Xenarthra) show a remarkable variation in size, geographic distribution and feeding patterns, and can be divided into four groups according to their dietary specializations: carnivore/omnivore (*Chaetophractus*, *Euphractus* and *Zaedyus*), generalist insectivore (fossorial) (*Chlamyphorus*), generalist insectivore (terrestrial) (*Dasypus*), and specialist insectivore (ants and termites) (*Priodontes*, *Cabassous* and *Tolypeutes*) (Redford, 1985).

The three genera of hairy armadillos, the carnivore/omnivores, show temporal and geographic variation in their diet which is more pronounced than in the other three feeding groups (Redford, 1985). Detailed and systematic studies on the diet of the carnivore/omnivores in natural conditions are needed for finer analyses of their patterns of trophic specialization. While research is wanting on the feeding ecology of nearly every edentate species (Redford, 1994), a notable exception among the hairy armadillos is Greegor's (1980) study on *Chaetophractus vellerosus* in northwestern Argentina. *C. vellerosus* combines an insectivorous diet with substantial intake of plant matter, especially *Prosopis* pods, in the winter.

The yellow armadillo, *Euphractus sexcinctus*, is the largest member of the carnivore/omnivore group and consumes many types of animal prey, including carrion, small vertebrates, ants (adults, larvae and cocoons), and plant matter such as fruits and tubers (Redford, 1985; Redford and Eisenberg, 1992; Bezerra *et al.*, 2001). Plant matter (especially fruit) makes up a major portion of the diet in the Pantanal region of Brazil (Schaller, 1983).

Euphractus sexcinctus is a common species ranging from central and eastern Brazil through Paraguay, eastern Bolivia and northern Argentina (Redford and Wetzel, 1985). It occurs in a wide variety of biomes, including the Amazon, Caatinga, Cerrado, Pantanal, Chaco and the Atlantic Forest (Silva-Júnior and Nunes, 2001). Within these biomes it most often inhabits savannas, forest edges and *campos cerrados*, a type of *cerrado* in which trees are absent and shrubs form an open layer (Eiten, 1979). The biomass of this species was estimated to be approximately 19 kg/km² for dry forest, flooded grassland, and open savanna in the Brazilian Pantanal (Schaller, 1983). In northeastern São Paulo it comprises 37% of total mammal road kills, or 2.56 kg/km, according to a survey of paved highways in the region (J. A. Tavares-Filho, unpubl. data; see below). In this study we examine the diet of the yellow armadillo and compare the results with available data on this species and other armadillos in the carnivore/omnivore group.

Methods
The interior of the state of São Paulo is presently covered with a mosaic of cattle pasture, cultivated fields (mainly sugar cane, cereals and fruit) and exotic plantations of *Pinus* and *Eucalyptus*. Scattered patches of *cerrado* and mesophytic semideciduous forest (*sensu* Rizzini, 1963) are still found in the interior of the state. The northeast of São Paulo is one of the most intensively cultivated areas of the state. Troppmair (1975) classifies the climate as Cwa according to Köppen (1936), characterized by a rainy season in the summer and a dry season in the winter; the rainfall varies between 1100 and 1300 mm, with a period of drought from May to September, and July being the driest month (Caldarelli and Neves, 1981).

From January 1981 to April 1984, 74 specimens of *Euphractus sexcinctus* were found as road kills along paved highways in northeastern São Paulo (within an area of ca. 30 km of radius around the point 21°06'S, 48°27'W) in the municipalities of Ribeirão Preto, Luis Antonio and Pradopolis. From these, it was possible to collect eight stomachs for dietary analysis, and the stomach contents of another four animals were collected at two locations in São Paulo (municipalities of Guareí and São José do Rio Preto) and two locations in Mato Grosso (municipalities of Cuiabá and Vila Bela) on highways crossing cultivated lands and gardens.

The stomach contents were preserved in the field in 10% formalin, and stored until analysis at the Departamento de Biologia, Universidade Federal de Mato Grosso, Cuiabá. The contents were washed with tap water through a metallic sieve (mesh diameter 1 mm). The filtrate (particles < 1 mm) included organic and inorganic residues (digested material, earth and sand), which were not included in the analysis. The material retained in the sieve was transferred to a glass plate for separation and identification of the food items under a dissecting microscope. The frequency of occurrence was calculated based on how many times a selected item occurred in the total number of stomachs. We estimated the volumetric percentage of each item based on the volume of an individual item in relation to the total volume of all items present in the stomachs.

Results

We identified 21 food items (62 total occurrences) in 12 yellow armadillo stomachs (Table 1), representing four main groups: plant material, insects, arachnids and vertebrates. Although plant material was frequent and diversified (grains, succulent stems and fruits), its estimated volume in the stomachs was only about 33%. Among the identified plant material, the only exception in terms of volume was corn (grains strongly chewed), which represented the third most abundant item in the material as a whole, and was present in half of the analysed contents. Although sugar cane dominates the cultivated landscape in northeastern São Paulo, it was poorly represented (as masticated stem fragments) in the dietary samples.

Of the four fruits identified, two are cultivated in orchards (orange and papaya), another is associated with human settlements (macaúba palm, *Acrocomia* sp.), and the fourth is typically wild (mangaba, *Hancornia speciosa*) and found in a number of vegetation types in the *cerrado*.

Insects comprised the bulk of the diet of *E. sexcinctus*, in both the frequency of occurrence and the amount of consumed food, representing more than 50% of the total volume analyzed. Ants (Formicinae, Myrmicinae, Dolichoderinae and Ponerinae) and dung beetles (Scarabaeidae) stood out in this food group, together reaching 57% in relative frequency and 86% of total insect volume. Of the nine stomachs containing ants, seven had combinations of winged adults, cocoons and larvae as the main content. Although other

TABLE 1. Stomach contents from 12 individuals of *E. sexcinctus,* collected as roadkills in agricultural areas of Mato Grosso and São Paulo, Brazil.

Food items	% Frequency	% Estimated volume
Plant matter		
Corn (grains)	9.6	18.9
Rice (grains)	1.6	1.0
Sugar cane (stems)	1.6	0.5
Orange (pulp and seeds)	3.2	1.2
Papaya (seeds)	1.6	3.2
Acrocomia sp. (pericarp)	1.6	1.2
Hancornia speciosa (seeds)	1.6	0.2
Unidentified fruits	1.6	0.2
Unidentified plants	11.2	6.2
Insects		
Hymenoptera (Formicidae)	14.5	22.0
Coleoptera (Scarabaeidae)	12.9	30.7
Isoptera (soldiers and workers)	6.4	1.0
Lepidoptera (larvae)	3.2	6.0
Orthoptera (Gryllidae)	1.6	0.08
Diptera (larvae)	3.2	0.08
Unidentified insects	6.4	1.5
Arachnids		
Araneae	4.8	1.2
Vertebrates		
Mammalia	6.4	2.2
Ophidia	1.6	0.8
Aves	1.6	0.5
Unidentified vertebrates	3.2	0.4

groups of insects appeared quite frequently, they contributed modestly to the general abundance. Fragments of large spiders occurred in 25% of the stomach contents.

Vertebrates made up only a small portion of the diet. Mammal remains in the stomachs included small rodents (Sigmodontinae), armadillo plates (probably from scavenging) and skin fragments of a large species of domesticated mammal, probably a pig. Other vertebrates included a snake and a bird, both small and found in the same stomach.

Discussion

In the absence of other data on the diet of the yellow armadillo, the present discussion is based on comparisons with Schaller (1983). Of the eight *E. sexcinctus* stomachs collected by Schaller (1983) in the Pantanal, seven were from the Acurizal ranch (17°45'S, 57°37'W) in the Serra do Amolar. This area is covered by a variety of swamp formations, gallery forest, semideciduous forest, and several subtypes of *cerrado* and savanna (Prance and Schaller, 1982). The estimated volumes supplied by Schaller (1983) were compared with the data for estimated volume in the present study. The occurrence of the different dietary groups and percent estimated volume from the two studies were compared using χ^2 goodness-of-fit tests (Magurran, 1988), and the results are compared with those obtained for *C. vellerosus* in northern Argentina (Greegor, 1980). Our data may represent the feeding tendencies of the yellow armadillo during the rainy season in northeastern São Paulo, in marginal road habitats. As a typical omnivorous/opportunistic feeder, the yellow armadillo is able to change its diet geographically; and the roadside provides scavengers with an additional supply of carcasses.

In intensively cultivated landscapes, the yellow armadillo is omnivorous, as previously reported by Redford (1985) and Redford and Wetzel (1985). Plant matter and insects made up the bulk of the diet in undisturbed (Pantanal) and intensively cultivated areas (northeastern São Paulo) (Table 2). We found no significant difference in the frequencies of occurrence of food groups between the two areas (χ^2 = 2.129, df = 3, p = 0.5461). We found a strongly significant difference (χ^2 = 43.755, df = 3, p << 0.001), however, when we compared the estimated volumes. This was due to the large quantities of plant matter in the stomachs from the Pantanal, and the substantial number of insects in the stomach contents from the agricultural region. Although the same food types are consumed, the quantities evidently vary greatly between the two areas. Shifts in diet based on geographic location are expected to be more pronounced among carnivore/omnivores than in other feeding groups (Redford, 1985), and the large geographical variation in the abundance of certain dietary items, as documented for the two areas compared here, supports this assumption.

Omnivory is characteristic of the diet of the euphractine armadillos (Redford, 1985), having been previously registered for *C. vellerosus* (Greegor, 1980). The diet of the yellow armadillo is evidently similar to that observed for *C. vellerosus*, with plant matter and insects composing the largest proportions of items in the stomach contents of both. Ants and beetles, very frequent in the diet of *C. vellerosus*, were the most common insects in the stomachs of *E. sexcinctus* in the agricultural areas of south-central Brazil.

Vertebrates account for a relatively large proportion of the diet of *Chaetophractus vellerosus* – approximately 14% by volume in the winter and 28% in the summer – when compared to the

TABLE 2. Comparison of frequency and estimated volume of different food types in the diet of *E. sexcinctus* in two regions of Central Brazil.

Food groups	Schaller (1983)*		Present study**	
	% occurrence	% volume	% occurrence	% volume
Plant matter	50.0	79.1	40.0	32.8
Insects	37.5	20.5	26.6	61.3
Spiders	6.2	0.3	10.0	1.2
Vertebrates	6.2	0.1	23.3	4.0

* Pantanal, eight stomachs analysed.

** Cultivated fields of São Paulo and Mato Grosso, 12 stomachs analysed.

common long-nosed armadillo, *Dasypus novemcinctus* (Greegor, 1980). Most of the vertebrates consumed by *C. vellerosus* were small rodents, reaching high frequencies: 23% in the summer and 19.4% in the winter. Small rodents also seem to be frequent in the diet of *E. sexcinctus*, occurring in three of 12 stomachs analysed here. A yellow armadillo collected in a soybean field in Goiás State, Brazil, had four individuals of *Calomys* sp. in its stomach (Bezerra *et al*., 2001), two of which were young (F. H. G. Rodrigues, pers. comm.).

Euphractine armadillos are predators of small and slow-moving prey. They lack an effective killing bite, however, subduing their prey by standing on it and tearing pieces with their jaws (Redford and Wetzel, 1985; Redford, 1994). In captivity, *E. sexcinctus* can kill large rats (Redford and Wetzel, 1985), and captive individuals have also been observed attacking a live deer fawn (*Mazama gouazoubira*) and a young rhea (*Rhea americana*) and trying to drag them into their burrows (J. C. Dalponte, pers. obs.). The presence of small rodents in the diet (Bezerra *et al*., 2001; present study) demonstrates that free-ranging yellow armadillos may occasionally capture small prey. In addition, one stomach of *C. vellerosus* contained four infant leaf-eared mice, *Phyllotis griseoflavus* (Greegor, 1980).

Armadillos which are carnivore/omnivores may also consume small rodents as carrion, and perhaps other vertebrates as well; but it is difficult to determine from stomach contents whether remains are from predation or from scavenging (Bisbal and Ojasti, 1980). Euphractine armadillos are known to eat rotting meat, and perhaps also the maggots associated with carcasses (see references in Redford, 1985). Larvae of necrophagous flies (Sarcophagidae) were found in two stomachs analysed in the present study, and in one they were associated with the remains of a small rodent. The remains of vertebrates in other stomach contents were not associated with sarcophagid fly larvae, although the presence of armadillo plates and pig skin would indicate carrion consumption.

The yellow armadillo has the largest and most powerful teeth of any armadillo (Moeller, in Redford, 1985), which may allow it to chew the meat, skin and small bones of a variety of carcasses. In fact, the high biomass of vertebrate carcasses concentrated on the highway (645,695 kg over a distance of 9,315 km; J. A. Tavares-Filho, unpubl. results) suggests this would be a plentiful food source for a potential carrion eater such as *E. sexcinctus*. It is easily sighted in open habitats, and aspects of its feeding ecology, in particular its foraging habits, could be easily studied.

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Bathing Behavior of Giant Anteaters (*Myrmecophaga tridactyla*)

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While following maned wolves (*Chrysocyon brachyurus*) during the dry season at Los Fierros (14°33.24'S, 60°55.40'W) in Parque Nacional Noël Kempff Mercado (Santa Cruz Department, Bolivia), we discovered an isolated pampa waterhole in a landscape depression, where mammals come to drink. The Los Fierros pampa has been experiencing an increasingly severe water shortage during the late dry season (August–October), and we have been following events at this water hole for three seasons.

When the water table drops below the ground surface, giant anteaters dig down to reach the water, as evidenced by a deep, fist-sized hole that is scarred with large claw marks. This activity by anteaters allows other animals – such as maned wolves, ocelots, raccoons, marsh deer, and birds – to reach otherwise inaccessible drinking water. Since 2002, we have been shoveling out and enlarging the hole and digging steps to enable mammals and birds to drink from water as deep as 90 cm below the ground surface, held within a layer of fine gray clay. During the wet season, which extends from November to June, there is a large pond over the site. To monitor animal activity in the dry season, we set a camera trap (TrailMaster 1550 or 550) aimed at the approach to the hole during September and October of 2002, 2003 and 2004.

We have acquired over 70 photos of giant anteaters coming to the water hole, including many photo pairs of the same individual, first arriving and then leaving the water source. The photos show many anteaters arriving dry, then leaving the hole soaking wet. They often emerge covered with gray mud from the soft clay of the water basin (Fig. 1). They are clearly rolling over within the waterhole, soaking their entire body and tail.

Although the anteaters were often completely coated with mud, we believe it likely that they were bathing, rather than mud-wallowing. We have a photo, taken when there was a small shallow pond present, of an anteater rolling in clean water at the ground surface. Bathing in water or wallowing in mud is rare in mammals that are