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Original investigation

Unraveling the cryptic life of the southern naked-tailed armadillo, *Cabassous unicinctus squamicaudis* (Lund, 1845), in a Neotropical wetland: Home range, activity pattern, burrow use and reproductive behaviour

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ABSTRACT

The natural history of the southern naked-tailed armadillo *Cabassous unicinctus squamicaudis* is not well known. Here, we provide basic information about burrow systems, home ranges, activity, morphometric measures, and reproductive behaviour. We monitored 10 individuals through VHF telemetry and direct observations in the central Pantanal of Brazil for 24 months. Males (2.06 km^2) had significantly larger home ranges than females (0.59 km^2) and home ranges of males overlapped with those of several females. There was very little overlap in ranges of the same sex and very few social interactions were observed. Southern naked-tailed armadillos dug convoluted galleries to forage, and, unless they used their entrance to exit, they emerged on average 2 m away (ranging from 0.01 m to 17 m) from the burrow entrance. When leaving their burrows, they spend on average 6.5 min above ground, travelling an average of 83 m (ranging from 1 m to 781 m) before going back underground. They do not return to sleep in a particular burrow, changing burrows frequently. The studied armadillos were diurnal, and spend 99.25% of the day underground, emerging only during the hottest period of the day (mid-afternoon). The southern naked-tailed armadillos should be classified as a subterranean species, rather than fossorial since they spent most of their time underground where foraging also takes place. Minimum densities of *C. u. squamicaudis* were estimated at 2.21 adults/km^2. Gestation was estimated to last for 4 months. Parental care of a single young lasted on average 4 months. Niche overlap between *E. sexcinctus* and *C. u. squamicaudis* in the study area is minimal.

Introduction

There are nine genera and 20 recognised species of armadillos (Cingulata: Dasypodidae) (Abba et al., 2015; Feijó and Cordeiro-Estrela, 2016). However, except for *Dasypus novemcinctus* (Linnaeus, 1758), the biology and behaviour of most armadillo species remains poorly known (Loughry et al., 2015; McDonough and Loughry, 2008; Superina et al., 2014). In an IUCN xenarthran assessment, Abba and Superina (2010) highlight the lack of basic biological information for most armadillo species, such as home range measures, population sizes, natural history and types of threats. Armadillos use burrows and shelters where they can spend long periods (Maccarini et al., 2015; McDonough and Loughry, 2008). In the relatively short time that most species spend above ground, they present a solitary behavior (McDonough, 1997). These behavioral characteristics coupled with the lack of an efficient and standardized methodology for capturing and monitoring armadillos hinders their study in the wild and contributes to the paucity of information on their ecology and natural history (Loughry and McDonough, 2013). Nevertheless, there is a need for factual knowledge on species biology and ecology to establish efficient

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conservation measures (Greene, 2005). In addition to traditional monitoring techniques, such as direct behavioral observation, the study of the spatial ecology of elusive burrowing species can be used to make inferences on their biological characteristics and ecological functions.

The body length of *Cabassous unicinctus squamicaudis* varies between 34.7 and 44.5 cm, and the tail length between 16.5 and 20 cm (Eisenberg and Redford, 1999). *C. u. squamicaudis* weighs about 1.6–1.8 kg, and has more scutes on the cephalic shield than any other *Cabassous* species (Wetzel, 1980). Females tend to be bigger than males, and consequently, have bigger burrows entrances (Carter and Encarnação, 1983). Individuals rotate their bodies while digging their burrows, giving burrow entrances an almost perfectly round shape (Borges and Tomás, 2008). *Cabassous* species are powerful diggers with several morphological adaptations to their digging habits, such as big claws, tibia and fibula fused proximally and distally, large tuberosities for strong muscular insertions, and long lever arms for the line of action of the principal muscles (Vizcaíno et al., 1999; Vizcaíno and Milne, 2002). This morphological adaptation can also be related to their myrmecophagous diet, composed almost exclusively of ants and termites (McDonough and Loughry, 2003; Redford, 1985).

Even though *C. unicinctus* has been the object of several field studies (Carter, 1985; Encarnação 1987; Bonato et al., 2008; Loughry et al., 2015), much remains to be learned about their behavior and ecology. *Cabassous unicinctus* is described as a solitary species and has been reported both as nocturnal (McDonough and Loughry, 2003) and as diurnal (Bonato et al., 2008; Encarnação, 1987). Almost nothing is known about its reproductive behaviour (Medri et al., 2011). In other species of the genus, only one individual is born at each reproductive event (Eisenberg and Redford, 1999).

In this study, we aim to unravel a broad array of previously unknown aspects of the natural history of the cryptic southern naked-tailed armadillo *Cabassous unicinctus squamicaudis*. As specific goals, we aim to provide morphometric measures, minimum home range and local density estimates, patterns of home range overlap, to describe activity and its relationship to ambient air temperature, to characterize burrows and its use, and to provide observations on reproductive behaviour. We compare our findings with previous descriptions for other armadillos species in the region and test the hypothesis that myrmecophagy (ant and termite eating) in armadillos is associated with relatively large home ranges, no re-use of burrows, and few social interactions. McDonough and Loughry (2008) argue that armadillos species whose diet relies heavily on ants and termites (*i.e. Tolypeutes* sp., *Cabassous* sp., *Priodontes* sp.), tend to have large home ranges, few social interactions, return only rarely to sleep in a burrow, and use digging as a predator escape strategy.

Material and methods

Study site

The study was carried out at the Fazenda Baia das Pedras in the central Pantanal of the state of Mato Grosso do Sul, Brazil (19°16′60″ S, 55°42′60″ W) between August 2012 and August 2014. The 140 km^2 cattle ranch comprises a mosaic of vegetation types and flooding regimes, but this study was concentrated in a 10 km^2 area of two paddocks that were cleared of most of their native vegetation over 20 years ago and planted with grass (*Brachiaria* spp., Poaceae) for pasture. This anthropogenic habitat was heavily degraded as it was near the cattle corral and the ranch house and, therefore, intensively used by livestock. Although the Pantanal is subject to a predictable monomodal flood pulse, the study area never floods. The climate is semi-humid tropical with a hot rainy season (October to March) and a cooler drier season (April to September, during which temperatures may drop due to cold fronts from the south). Mean annual temperature is 25.4°C, ranging between 20.7 and 28° C. (Soriano, 2000).

Capture and handling

We engaged in field activities monthly, for an average of two weeks per month, for a total of two years. We carefully surveyed part or all of the study area by foot or quad bike several times on each monthly expedition to search for fresh sand mounds characteristic of *C. u. squamicaudis* burrow entrances. Once the sand mound was located, the researcher would move downwind at a distance of at least 15–20 m from the entrance to wait for the animal to emerge. Armadillos are primarily guided by odor and tactile stimuli, rather than vision (Emerling and Springer, 2015), hence, this strategy decreases the chance of the animal noticing the researcher in the area. Since they are slow-moving animals and their main form of defence is to dig rapidly and disappear underground (McDonough and Loughry, 2003), the armadillos were caught by hand and immediately placed in a small crate for transportation to the field laboratory at the ranch (<3 km away). There they were weighed, anesthetized and subjected to surgical implantation of intra-abdominal VHF transmitters (model IMP 130 Telonics, Mesa, Arizona, USA). Transmitter weighed 19 g, ∼1.1% of adult body weight. While anesthetized, twelve body measurements were taken from each individual to characterize the morphometry of males and females (Table 1). Differences between sexes for each morphometric measure was assessed through a *t*-test. The armadillos were maintained for 12–24 h in a holding box for full recovery and then released in the burrow where it was captured. Each captured individual was assigned and individual identity composed of a letter indicating its sex (F – female, M – males) and a serial number (e.g. F1, female #1).

Direct observations

To assess the basic behaviour of the species and guide monitoring efforts through VHF telemetry and direct observation, we used a focal animal sampling approach (Altmann, 1974) to monitor the first individual captured. We performed continuous direct observation for 72 consecutive hours, one month after its initial capture. Since this individual never moved during the night and only emerged above ground to change locations once or twice during the day, we concentrated our monitoring efforts during the daytime.

We also used a focal animal sampling approach to characterize the species burrowing behaviour, activity patterns, and general observation. Each day a random, previously tagged, individual was selected for intensive observation from 8 a.m. until 5 p.m. An observer sat with a pair of binoculars downwind 15–20 m from the burrow (to avoid any interference or behavioural modification) waiting for the animal to emerge. Once the animal emerged, he recorded: time of emergence from the burrow, the duration of the period spent above ground and the distance between the point of emergence and the point of establishment of a new burrow. Through this method, we were also able to evaluate if the animal entered and exited a burrow through the same place and, if not, we would measure the distance between its entrance and its exit.

Burrow holes were measured (two measures of the diameter perpendicular to each other), described and finally categorized according to their basic structure and use. We identified and distinguished three types of excavations dug by *C. u. squamicaudis*: “Sand-mound” hole; “Rat-Type” hole, and “Vertical cylindrical” hole. Sand-mound and Rat-Type holes describe the signs left when

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