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Comments/Reflections

Spontaneous ingestion of water by a free-ranging maned sloth, *Bradypus torquatus*, in the Ibura National Forest, northeastern Brazil

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Abstract

Water is an important limiting factor in the ecology of many animals, and even in rainforests, arboreal mammals, such as sloths, may have limited access to water sources. Here, we describe the spontaneous ingestion of water by a free-ranging three-toed sloth (*Bradypus torquatus*). The event occurred in the Ibura National Forest, in northeastern Brazil, where a sub-adult *B. torquatus* was monitored over three days in January, 2014. On the third day, the sloth was feeding on mature leaves and, at 16:22 h, it began raining heavily. Once the rain ceased, the sloth began to ingest the rainwater trickling down a vertical branch by licking it, and continued to ingest water for approximately 26 minutes. This behaviour indicates that the water was a valuable resource for this sloth, and sheds new light on the previous assumptions that these animals are able to satisfy

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their water requirements through their diet alone. This observation, together with an overview of the data on the ingestion of water by arboreal mammalian folivores, indicates that the direct ingestion of water may depend on specific local conditions, in particular, the availability of water sources, as well as the specific necessities of the mammal. As the lack of previous records of this behaviour in sloths is likely due to the cryptic behaviour of these animals, this finding highlights the importance of continuous, long-term behavioural monitoring for a more complete understanding of sloth ecology.

Keywords
arboreal folivores, rainwater, water drinking, seasonal patterns.

1. Introduction

The geographic distribution of a species may be limited by a range of factors, in particular the availability of trophic resources, including water. Humid environments, such as tropical rainforests, tend to have a more diverse biota than more arid systems, a pattern found in animals as diverse as insects (Novotny et al., 2006), birds (Weir & Schluter, 2007), and primates (Gouveia et al., 2014). While finding water is a fundamental challenge in arid environments (Chew, 1961; Schmidt-Nielsen, 1964; Nicolson, 1980), many arboreal animals may have only limited access to sources of water, even in rainforest ecosystems (Degabriele & Dawson, 1979, Ferrari, 1991). However, many arboreal mammalian folivores — i.e., the thin-spined porcupine, *Chaetomys subspinosus* (see Giné, 2009); the koala, *Phascolarctos cinereus* (see Degabriele & Dawson, 1979); primates such as *Alouatta* spp. and *Procolobus* spp. (see Starin, 2002; Dias et al., 2014), and the sloths, *Bradypus* spp. and *Choloepus* spp. (see Gilmore et al., 2008) — are able to satisfy most of their water requirements from their food. Typically, these mammals may absorb humidity (dew or moist) from the leaves they ingest (Milton, 1979; Nagy & Montgomery, 1980; Davies et al., 1988) or metabolically (Milton, 1979; Nagy & Montgomery, 1980), through the oxidation of the plant matter, rather than through the direct ingestion of water from standing sources.

The sloths of the genus *Bradypus* are an extreme example here. These strict folivores have extremely slow rates of food passage (Foley et al., 1995) and poikilothermic-like thermoregulatory mechanisms (McNab, 1978; Giné et al., 2015; Cliffe et al., 2015, 2018), which appear to be their physiological response to a diet poor in nutrients (McNab, 1978; Chiarello, 1998b). The extraordinarily low metabolic rate of these sloths, which is 40–79% lower than that expected for an animal of comparable body size, is similar to that

of a hibernating mammal (Nagy & Montgomery, 1980; Pauli et al., 2016; Cliffe et al., 2018).

Despite the long history of behavioural research on sloths, suborder Folivora (Sunquist & Montgomery, 1973; Chiarello, 1998a,b; Lara-Ruiz & Chiarello, 2005; Giné et al., 2015), the ingestion of water by these animals has been observed only very rarely. In fact, the only published reports (see Britton, 1941; Meritt, 1985) have been derived from observations of captive animals. Here, we describe the ingestion of water by a free-ranging maned sloth, *Bradypus torquatus*, in an area of Atlantic forest in northeastern Brazil.

2. Material and methods

The event described here was observed during the long-term behavioural monitoring of free-ranging maned sloths, *Bradypus torquatus*, at the 144-ha Ibura National Forest, the INF (10°51′ S, 37°07′ W) in the municipality of Nossa Senhora do Socorro, Sergipe, Brazil, between August 2012 and May 2014. The INF encompasses a mosaic of vegetation types, including semi-deciduous forest at different stages of regeneration, and open areas (for details, see Santana et al., 2017), surrounded by mangroves (see Beltrão-Mendes et al., 2020) in which sloths were never observed (NMA, pers. obs.). There are two principal natural bodies of water within the INF, the Buti stream and the Cotinguiba River. Smaller temporary pools and streams are also present, primarily during the rainy season (The authors, pers. obs.). The local climate is tropical megathermal, category *As* in the Köppen classification (Alvares et al., 2013), with a dry season during the austral summer, and most rainfall occurring between April and August.

A number of mammals are found at the INF, with both *B. torquatus* and *Bradypus variegatus* occurring sympatrically at the locality (see Albuquerque et al., 2014; Beltrão-Mendes et al., 2020). In the Brazilian state of Sergipe, the distribution of *B. torquatus* is limited to the Atlantic forest (Chagas et al., 2009), as predicted by Moreira et al. (2014), and up to now, this species has not been recorded north of the Sergipe River (R.B.-M., pers. obs.). The presence of sloths in the INF is attributed to the historical release of animals by local environmental agencies (Albuquerque et al., 2014), although the study site is located close to the northern limit of the distribution of *B. torquatus* in the study region (Hirsch & Chiarello, 2012), and presents similar rainfall patterns and overall environmental conditions

(R.B.-M., pers. obs.). During a long-term study, we monitored the behaviour of 11 untagged individuals of *B. torquatus* by focal animal sampling (Altmann, 1974). Behavioural records were collected by continuous sampling, with a total sampling effort of 227 hours of monitoring.

3. Results

We monitored one focal subject, a sub-adult *B. torquatus*, for a total of 25 hours between 25 and 27 January 2014, with 11 hours of continuous monitoring being conducted on 27 January, starting at 05:58 h, and continuing until the late afternoon. During this monitoring session, the focal animal spent most of its time moving (48.3%), feeding (25.4%) and resting (20.2%). By the late afternoon, the sloth was feeding on the mature leaves of *Cupania racemosa* (Vell.) Radlk. and *Cupania revoluta* Radlk., foraging, and moving, when it began to rain heavily, causing the sloth to remain motionless for approximately one minute. Once the rain had stopped, the subject moved to a smaller, adjacent tree, and began to ingest the rainwater trickling down a near-vertical branch (Figure 1). The sloth remained in a vertical 'climbing' position (see Urbani & Bosque, 2007) as it brought its lips into contact with the surface of the branch to intercept the water.

The ingestion of water began at 16:22 h and ended at 16:48 h, lasting approximately 26 minutes, although the sloth stopped drinking for around six minutes at 16:31 h and climbed 70 cm up the branch before resuming this activity. The whole sequence of events was recorded in a video file that can be seen at 10.6084/m9.figshare.13378811. Once the rain had stopped, the sloth resumed its previous activities, that is, moving through the forest, foraging and feeding on mature leaves. The sloth did not ingest water again during the rest of the daylight hours, with monitoring being terminated just before dusk.

4. Discussion

This observation is the first published record of the ingestion of water by free-ranging sloths, and provides important insights into the physiological requirements of *B. torquatus*, in particular, and the genus *Bradypus*, in general. Up to now, sloths were assumed to satisfy their water requirements metabolically through their diet (Meritt, 1985; Gilmore et al., 2000, 2008), and Nagy & Montgomery (1980) concluded that this process was so efficient

Figure 1. A maned sloth (*Bradypus torquatus*) drinking water from the bark of a tree during behavioural monitoring at the Ibura National Forest in Nossa Senhora do Socorro, Sergipe, northeastern Brazil. Image captured from the video footage.

that free-ranging sloths do not drink water, even when it is raining. These authors estimated water influx and efflux rates in wild sloths that were nearly equal, with a mean of about 38 ml/kg·per day, with their water requirements being satisfied entirely by metabolic water (approximately 4.2 ml/kg·per day) and by the water content of the leaves they consume, which is typically 78% in young leaves and 65% in mature leaves (Nagy & Montgomery, 1980).

While the lack of records of drinking in wild sloths supports this conclusion (Table 1), this may simply be due to the paucity of field studies, given that captive individuals of both sloth genera, *Bradypus* and *Choloepus*, have been observed drinking water (Britton, 1941; Meritt, 1985). Radio-tagged individuals of *B. torquatus* were never seen drinking free-standing water in the wild (Chiarello, 1998a,b; Chiarello et al., 2004; Castro-Vasquez et al., 2010; Giné et al., 2015), even though the existing behavioural studies amount to thousands of monitoring hours, continuous or not, on both rainy and dry season periods.

Table 1.
Records (or absence) of the direct ingestion of water in selected folivorous arboreal mammals (captive and free ranging).

Order/Species	Diet	Type of study	Water consumption (number of records)		Season	Reference
			Yes	No		
MARSUPIALIA						
Phascolarctos cinereus	Folivore	Captive	–	1	Not reported	Cork et al. (1983)
		Captive	2	–	Not reported	Harrop & Degabriele (1976); Degabriele & Dawson (1979)
		Free-ranging	5	–	Hot season; May increase in hot season	Ellis et al. (1995, 2010); Lunney et al. (2012); Mella et al. (2019, 2020)
XENARTHRA (FOLIVORA)						
Bradypus spp.	Folivore	Captive	1	–	Not reported	Britton (1941)
Bradypus torquatus	Folivore	Free-ranging	–	8	Not reported	Chiarello (1998 a,b); Chiarello et al (2004); Cassano (2006); Barreto (2008); Cassano et al. (2011); Falconi et al. (2015); Giné et al. (2015)
			1	–	Dry season	Present study
Bradypus tridactylus	Folivore	Captive	–	1	Not applicable	Moura Filho et al. (1983)
Bradypus variegatus	Folivore	Free-ranging	–	6	Not applicable	Nagy & Montgomery (1980); Urbani & Bosque (2007); Bezerra et al. (2008); Castro-Vásquez et al. (2010); Silva et al. (2013); Neam & Lacher Jr. (2015)
Choloepus spp.	Folivore	Captive	2	–	Not reported	Britton (1941); Meritt (1985)
Choloepus hoffmanni	Folivore	Free-ranging	–	1	Not reported	Alvarez et al. (2004)

Table 1.
(Continued.)

Order/Species	Diet	Type of study	Water consumption (number of records)		Season	Reference
			Yes	No		
PRIMATES						
Alouatta belzebul	Folivore	Free-ranging	1	–	Rainy season	Bonvicino (1989)
Alouatta caraya	Folivore/ frugivore	Free-ranging	1	–	Rainy season	Bicca-Marques (1992)
			1	–	Hot season	Giudice & Murdy (2000)
Alouatta clamitans	Folivore	Free-ranging	–	1	Not reported	Miranda & Passos (2004)
			2	–	Dry season	Miranda et al. (2005); Moro-Rios et al. (2008)
Alouatta fusca	Folivore/ frugivore	Free-ranging	–	2	Not reported	Mendes (1989); Chiarello (1992)
			1	–	Dry season	Steinmetz (2001)
Alouatta guariba	Folivore	Free-ranging	–	1	Not reported	Aguiar et al. (2003)
Alouatta palliata	Folivore/ frugivore	Free-ranging	–	2	Not reported	Gaulin et al. (1980); Chapman (1988)
			3	–	Dry season; Rainy season	Glander (1978); Gilbert & Stouffer (1989); Serio-Silva & Rico-Gray (2000)
Alouatta pigra	Folivore/ frugivore	Free-ranging	–	1	Not reported	Coelho et al. (1976)
			1	–	Hot season	Dias et al. (2014)
Ateles geoffroyi	Frugivore/ folivore	Free-ranging	–	1	Not reported	Coelho et al. (1976)
			1	–	Dry season	Chapman (1988)
Ateles chamek	Frugivore/ folivore	Free-ranging	1	–	Not reported	Ferrari (1991)
Presbytis melalophos	Folivore/ frugivore	Free-ranging	–	1	Not reported	Davies et al. (1988)

Table 1.
(Continued.)

Order/Species	Diet	Type of study	Water consumption (number of records)		Season	Reference
			Yes	No		
Presbytis rubicunda	Folivore/ frugivore	Free-ranging	–	1	Not reported	Davies et al. (1988)
Procolobus badius temminckii	Folivore	Free-ranging	1	–	Rainy season	Starin (2002)
Procolobus rufomitratus	Folivore	Free-ranging	–	1	Not reported	Decker (1994)
Procolobus kirkii	Folivore	Free-ranging	1	–	Year round	Nowak (2008)
Trachypithecus cristatus	Folivore	Captive	–	1	Not reported	Bauchop & Martucci (1968)
RODENTIA						
Chaetomys subspinosus	Folivore	Free-ranging	–	6	Not reported	Chiarello et al. (1997); Oliveira (2006); Giné et al. (2010, 2012); Souto-Lima et al. (2010); Oliveira et al. (2012)
Coendou spinosus	Folivore	Free-ranging	–	1	Not reported	Abreu et al. (2017)
Sphiggurus villosus	Folivore	Free-ranging	–	1	Not reported	Passamani (2010)

The observation reported here, together with the data on other arboreal mammalian folivores (Table 1), indicate that the direct ingestion of water is dependent on specific local conditions, in particular, the availability of water sources. In the specific case of the sloths, this behaviour is probably the result of a combination of factors, in addition to the availability of water, such as the ambient temperature, the composition of the diet, and the humidity of the ingesta in the digestive tract of the animal (Milton, 1979; Nagy & Montgomery, 1980; Davies et al., 1988; Giné et al., 2015; Cliffe et al., 2015, 2018).

The event recorded here occurred at the peak of the dry season, with a total precipitation of only 20 mm being recorded in the month of January 2014. A simultaneous study of foliar phenology in the INF during the same period as that of the present study (Santana et al., 2018) also recorded a peak of leaf-fall in January 2014, when the rates of leaf budding were the lowest recorded in the study period, indicating an extremely reduced availability of young leaves. This implies that the focal sloth would have been consuming more mature leaves than normal during this period (95% of the records). These leaves tend to have a much higher fibre content and less water than young leaves, and would thus be more difficult to digest (Nagy & Montgomery, 1980; Milton, 1979; Davies et al., 1988). Any reduction in the humidity of the diet would likely affect the immediate capacity of the animal to extract the water content or metabolic water from its ingesta (Nagy & Montgomery, 1980), and would favor the direct ingestion of water from leaves or even the animal's own body hair.

Mella et al. (2020) report the koalas licking water trickling down the trunks and branches of trees during or immediately after rainfall at the You Yangs Regional Park, in Victoria, Australia, a similar water drinking behaviour to that recorded in the present study. These animals are frequently observed searching for sources of water, even man-made ponds (Cork et al., 1983; Nagy & Martin, 1985; Sullivan et al., 2003; Ellis et al., 2010; Lunney et al., 2012; Mella et al., 2019, 2020). Differences in the frequency of water drinking in sloths and koalas may be enhanced by environmental factors. Koalas are typically found in relatively harsh, seasonal and semi-arid forests affected by prolonged drought, high temperatures, and secondary effects of the CO_2 levels that alter leaf composition, which would likely increase the water requirements in these marsupials (Clifton et al., 2010; Ellis et al., 2010; Lunney et al., 2012; Mella et al., 2019, 2020), whereas sloths are typical of

more stable, moist forests, with more amenable ambient temperatures and higher precipitation (see Moreira et al., 2014). In the current context of climate change, however, recent deforestation and habitat fragmentation imply greater edge effects, the prolongation of droughts, and the accentuation of seasonal effects, which together create new challenges for sloths.

A number of other arboreal folivores are known to ingest water, and a literature search revealed a total of 24 studies (including the present one) that have reported this behaviour in these mammals, both in the wild and in captivity (Table 1). However, only primates and marsupials have been observed ingesting water in the wild, with the largest number of records (and species) involving the Neotropical howler monkeys (genus *Alouatta*).

As in the present study, most of the records of the ingestion of water by free-ranging arboreal folivores have been obtained during the dry or hot season. Water sources include epiphytic bromeliads, ground water, tree holes, and the animals' own body hair. *Alouatta caraya* and *Alouatta pigra*, for example, have been observed drinking water from tree holes, either directly or by immersing a hand in the water and then licking it from the hair (Giudice & Murdy, 2000; Dias et al., 2014), while Ferrari (1991) observed *Ateles chamek* (cf. *Ateles paniscus*) using its tail to access a water source in a similar manner. Both *Alouatta fusca* and *Alouatta guariba* have also been recorded drinking water directly from the phytotelmata of bromeliads (Steinmetz, 2001; Miranda et al., 2005). Unlike primates, however, sloths are unable to adopt a pronograde position (Mendel, 1985; Urbani & Bosque, 2007; Nyakatura, 2012), which may limit their capacity to reach some sources of water, in particular those found in tree holes or bromeliads (see Mendel, 1985; Urbani & Bosque, 2007 for further details on sloth postural behaviour). The postural capabilities of the sloths may nevertheless favor some positions that are not feasible to pronograde mammals, as seen in some anecdotal observations of wild animals (see for *Choloepus*: https://youtu.be/kis26nxGFo4; *Bradypus*: https://youtu.be/qfQDdiyMZ7w). It is important to note, however, that even these postures are limited by the need for suitable pendulum supports, as observed in these videos.

As the cryptic habits of sloths make them difficult to observe in general (Queiroz, 1995; Chiarello, 2008; Castro-Vásquez et al., 2010), the probability of recording relatively rare and brief activities, such as licking water from a substrate, during monitoring in the field may be greatly reduced, a problem exacerbated by the huddled posture typically adopted by these animals

during much of their activity time. In addition, any observations during rainy weather presents specific challenges for the use of binoculars (lens fogging or damage) or data-logging devices (field books or audio-recorders), which may often force the observer to pause data collection. Overall, then, the event recorded in the present study would appear to indicate that the lack of previous records of water drinking in free-ranging sloths may have been the result of a combination of the rarity of this activity and the cryptic behaviour of these animals, rather than any intrinsic characteristic of sloth ecology. This highlights the importance of continuous, long-term behavioural monitoring for a more complete picture of sloth ecology, and in particular the understanding of the rarest or most subtle behaviour patterns.

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Appendix

Video 1. Video recording of a maned sloth (*Bradypus torquatus*) drinking water from the bark of a tree during behavioural monitoring at the Ibura National Forest in Nossa Senhora do Socorro, Sergipe, northeastern Brazil.