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Marking behaviours of jaguars in a tropical rainforest of southern Mexico

Large solitary felids have to communicate indirectly with their conspecifics to advertise their presence and social status, to find mates and to maintain their land tenure system. However, there is little information about the social behaviour of jaguars *Panthera onca*. We investigated the marking behaviour of several jaguars on a trail located within the Montes Azules Biosphere Reserve BR, southern Mexico. We evaluated the different marking behaviours of jaguars and the jaguar preferences to mark certain trees. We found that jaguars preferred the highest trees and those with a wider diameter at breast height for claw marking. Recorded marking behaviours included: claw marking a tree, spraying urine and rubbing the tree. One male jaguar visited the marking tree at three different occasions accompanied by two different females. The most interesting aspect of our findings is that at least seven individuals (four males and three females) used the exact same tree as an important communication spot.

Most of large felids are nocturnal, solitary, live in dense forest and have extensive home ranges (Sunquist & Sunquist 2009, Macdonald et al. 2010). Therefore, these species have to communicate indirectly with their conspecifics to advertise their presence and social status, to search for mates and to maintain their land tenure system (Bothma & le Riche 1995, Molteno et al. 1998, Bothma & Coertze 2004, Ghoddousi et al. 2008, Harmsen et al. 2010). The species of the *Panthera* genus can communicate with their conspecifics over long distances using vocalisations (Sunquist & Sunquist 2009). However, marking is virtually used by most large felid species (Smith et al. 1989, Mellen 1993, Allen et al. 2014, Vogt et al. 2014). Allen et al. (2016) conducted a systematic review of communication behaviours of each felid species. Marking behaviour in the species of the *Panthera* genus mainly involves spraying urine, depositing faeces, ground scrapes, rubbing trees or other objects and claw marking a tree (Smith et al. 1989, Bothma & le Riche 1995, Ghoddousi et al. 2008, Harmsen et al. 2010).

There is little information about the social behaviour of jaguars. Similarly to other large felids, jaguars communicate with their conspecifics through vocalisations, scrapes, scent marking and claw marking (Leopold 1959, Rabinowitz & Nottingham 1986, Harmsen et al. 2010, Harmsen et al. 2016). Previous studies have suggested that only male jaguars are involved in scent marking, and that several individuals can mark at one single location (Harmsen et al. 2016). The understanding of marking behaviours in jaguars and in other wild felids is relevant because differences in mark congregations and behaviours could indicate differences in social structure, spatial behaviour and density; and this ultimately could contribute significantly to improve monitoring programmes of the species (Allen et al. 2015, Allen et al. 2016, Harmsen et al. 2016). Here we describe the marking behaviour of several jaguars on a trail located within the Montes Azules BR, southern Mexico. We evaluated the number of individuals that mark on this trail, the different marking behaviours exhibited and the species and the characteristics of trees used by jaguars for marking.

In October 2014, we identified a tree of *Terminalia amazonia* neighbouring a trail with several scratching marks that we identified as claw marks. The tree had a diameter of 66 cm at breast height DBH, a hight of 20 m, and the tree trunk was inclined by an angle of 45°. We placed a camera trap in front of this tree, which was operating from November 2014 to March 2015 and from July 2015 to December 2015. We identified the different jaguar individuals in photographs and videos based on their individual spot patterns, and we recorded all different

Fig. 1. Some of the jaguar behaviours recorded with the camera trap placed in front of the marked tree: a) mating; b) claw marking; and c) sniffing (Photos Natura & Ecosistemas Mexicanos A.C).

marking behaviours of pictured or filmed jaguars (Silver et al. 2004, Allen et al. 2016; Supporting Online Material SOM Videos V1 & V2).

On 14 November 2014, we photographed two jaguars mating right in front of the tree (Fig. 1a). After this event, we registered 33 different events that included seven jaguars (four males and three females) visiting the tree. According to the photographs and videos obtained, we recorded jaguars conducting the following behaviours: 1) Claw marking a tree, which involves climbing the tree and scratching it, 2) only climbing the tree, 3) spraying urine around the tree, 4) sniffing around the tree, 5) walking along the trail and 6) rubbing the tree or other nearby trunks (Fig. 1a-c, SOM Table T1).

Most of the recorded events corresponded to the same male jaguar (M-02), which was recorded on three different occasions accompanied by two different females (F-01 & F-05; SOM T1). This individual has been recorded in the area since 2010 and is the individual with most records in the study area in recent years. The number of times that M-02 exhibited marking behaviour suggests that he is the dominant male in the area (Harmsen et al. 2016, Allen et al. 2015). Female F-01 has been recorded in the area since 2007 (de la Torre & Medellín 2011), and the records obtained since then suggest that she still was resident during our study. Female F-05 has recently (since 2013) been recorded in the study area. She also has been recorded on the other side of the Lacantún River, outside the Montes Azules BR, within the forest fragments near the local communities of Marqués de Comillas region. All the individuals recorded, with exception of the male M-04, claw marked the tree in at least one occasion. M-04 has only been detected on few occasions in the area. The fact that he did not leave signs behind himself suggests that he possibly was a transient animal or preferred to only register the presence of resident individuals with-out advertising his own presence to avoid confrontation (Allen et al. 2015, Allen et al. 2016, Harmsen et al. 2016).

Additionally, on the same trail, we recorded seven other trees with claw marks, belong-ing to three different tree species: *Guettarda combsii*, *Calophyllum brasiliense* and *Terminalia amazonica*. The DAP of the marked trees ranged from 26 to 100 cm and the height from 8 to 22 m (SOM T2). We compared the marked trees with the relative abundance of the tree species identified on the same trail using a vegetation plot (80 x 20 m; 149 trees measured; 40 species identified). Based on this study, we assume that jaguars have no preferred tree species for claw marking because *Guettarda combsii* and *Calophyllum brasiliense* are the most abundant species in this area. However, comparing the height and DBH mean of the marked trees with those measured in the vegetation plot, we found that jaguars preferred the highest trees ($t = -7.78$; $d.f. = 5.06$; $p < 0.001$) and those with a wider DAP ($t = -3.66$; $d.f. = 7.04$; $p < 0.01$) for claw marking on this trail (SOM T3). These findings differ with those from Harmsen et al.

(2016), who reported that jaguars preferred young vascular plants and avoid tree trunk as rubbing substrate.

Our results suggest that although jaguars have extensive home ranges and exhibit territorial behaviour in core areas (Azevedo & Murray 2007, de la Torre et al. 2017), they seem to have important communication spots within the forest. Other studies with large felids showed that marks are not randomly distributed but strategically placed so that they can be easily detected (Smith et al. 1989; Bothma & le Riche 1995, Harmsen et al. 2010). Scrapes or claw marks do not only serve as visual signals for jaguars, but jaguars may also leave traces of their inter-digital glands with them which act as olfactory signals (Bothma & le Riche 1995, Ghoddousi et al. 2008, Allen et al. 2014). Marks are continuously updated to inform other individuals that the occupant of the area is still around or was recently there (Vogt et al. 2014). Although very little is known about the chemistry of social odours of jaguars and other large felids, the marking behaviour of these species has generally been interpreted as a form of communication between individuals to indicate their presence, territorial status, or their reproductive status (De Boer 1979, Smith et al. 1989, Allen et al. 2014).

Our study highlights that solitary wild felids exhibit fidelity to sites used for communication and that several individuals can use exactly the same sites to communicate with their conspecifics (Allen et al. 2016). Furthermore, the study illustrates the importance of camera trapping, especially video traps, to study the behaviour and communication of wild felids (Harmsen et al. 2016, Allen et al. 2016). Future studies with the aim to understand specific differences between individuals, sex, age and relationships in the function of marking behaviour should include a combination of camera trapping with experimental design and genetic identification of studied individuals.

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Supporting Online Material SOM Video V1 & V2 and Tables T1-T3 are available at www.catsg.org.

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SOM T1. Number and characteristics of recorded behaviours per jaguar individual.

		Mating	Claw marking	Climbing	Urine spraying	Smelling	Walking	Rubbing
Females	F-01	1*	1	1		1		
	F-05		1*			1	2*	
	F-06		1	1			1	
Males	M-02	1	7	6	1	3	5	5
	M-03		2	1	1			
	M-04					1		
	M-07		2	2			2	2

* Recorded in one occasion with the male M-02

SOM T2. Characteristics of trees marked by jaguars on the monitored trail, including their height and diameter at breast height DAP.

Species	Height (m)	DAP (cm)
Guettarda combsii	20	65
	18	65
	22	90
Calophyllum brasiliense	8	27
	20	90
	12	45
Terminalia amazonica	15	100

SOM T3. Height and DAP mean of the trees used by jaguars for claw marking and the trees measured using a vegetation plot of 80 x 20 m which intersected the trail.

Species	N	Height (m)	DAP (cm)
Trees with claw marking	7	16.42 ± 5.02	68.85 ± 26.50
Trees without claw marking	149	11.74 ± 8.51	9.45 ± 7.91