

# Present but not detected: new records increase the jaguar's area of occupancy in the coastal Atlantic Forest

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**Abstract** The jaguar *Panthera onca* has lost 85% of its habitat in the Atlantic Forest, where it persists in small and isolated populations in the largest fragments. In the absence of recent records, the jaguar had previously been presumed extinct in the large Atlantic Forest fragments of the Serra do Mar in southern Brazil. However, as this region is mountainous, densely forested and difficult to access, the jaguar could still be present, but undetected. We carried out an intensive survey using camera traps and interviews with local people in a large (c. 6,500 km<sup>2</sup>) forest block. During 2011–2019, 98 camera-trap stations were established (14,239 trap-days), and 249 interviews were conducted in 102 grid cells of 5 × 5 km. We obtained the first images of the jaguar in the region, from which five individuals were identified, and interviewees provided records of the jaguar in 24 grid cells. Our findings increase the range of this species in the Atlantic Forest by 9%, and we recommend that the area should be classified as a jaguar conservation unit. As the area we surveyed is adjacent to the Serra do Mar jaguar conservation unit, the combined area of 19,262 km<sup>2</sup> is the largest priority area for jaguar conservation in the Atlantic Forest. This proposed jaguar conservation unit could serve as a vital source of jaguar individuals for the coastal forests further south. We recommend that surveys are extended southwards to Santa Catarina state to determine whether the presumed extinction of jaguars in this state is another case of a false absence.

**Keywords** Brazil, camera trap, carnivore, conservation, jaguar, *Panthera onca*, protected area, Serra do Mar

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Received 17 July 2021. Revision requested 26 November 2021.

Accepted 1 February 2022. First published online 4 August 2022.

Supplementary material for this article is available at [doi.org/10.1017/S0030605322000151](https://doi.org/10.1017/S0030605322000151)

The jaguar *Panthera onca*, the largest Neotropical felid, is currently limited to half of its original range and its populations are threatened by habitat loss, poaching and declining prey populations (Swank & Teer, 1989; Sanderson et al., 2002; Quigley et al., 2017). In the Atlantic Forest, one of the most threatened tropical forests (Myers et al., 2000), the jaguar has already lost 85% of its habitat, and its population is estimated to be < 300 reproducing individuals distributed in small subpopulations and restricted mainly to the largest forest fragments (> 1,000 km<sup>2</sup>) (Paviolo et al., 2016). However, jaguars were previously believed to be extinct in the large fragments of the coastal forest of the Serra do Mar in southern Brazil (Paviolo et al., 2016).

The most recent documented records of the species in this region were faecal records from 1997 (Leite & Galvão, 2002) and track and vocalization records from 2006 (Mazzolli & Hammer, 2008) in the state of Paraná. As these forests lie in one of the largest continuous remnants of the Atlantic Forest (c. 6,500 km<sup>2</sup>), connecting preserved forest areas across a coastal mountain range (Fig. 1), and are difficult to access, the absence of jaguar records could be a result of the lack of surveys rather than necessarily reflecting the absence of the species. Over 8 years we therefore surveyed a large forest fragment in the Serra do Mar, culminating in the confirmation of the presence of the species in the region and in unique photographic records. We discuss the implications of these findings for jaguar conservation in the Atlantic Forest.

The coastal forest of Serra do Mar in Paraná State is mostly mountainous and ranges from the coast to the highest peak at 1,877 m (Maack, 2012). The region comprises a mosaic of protected areas ranging from restrictive (e.g. Reserves, Parks, ecological stations) to less restrictive protected areas (e.g. Environmental Protected Areas), and small cities and rural villages located mainly along the coastal plain and roads, where a historical process of deforestation and forest degradation took place.

During 2011–2012 we used 41 camera-trap stations to survey four private nature reserves totalling 220 km<sup>2</sup> (Fig. 1; Fusco-Costa & Ingberman, 2013; Fusco-Costa,

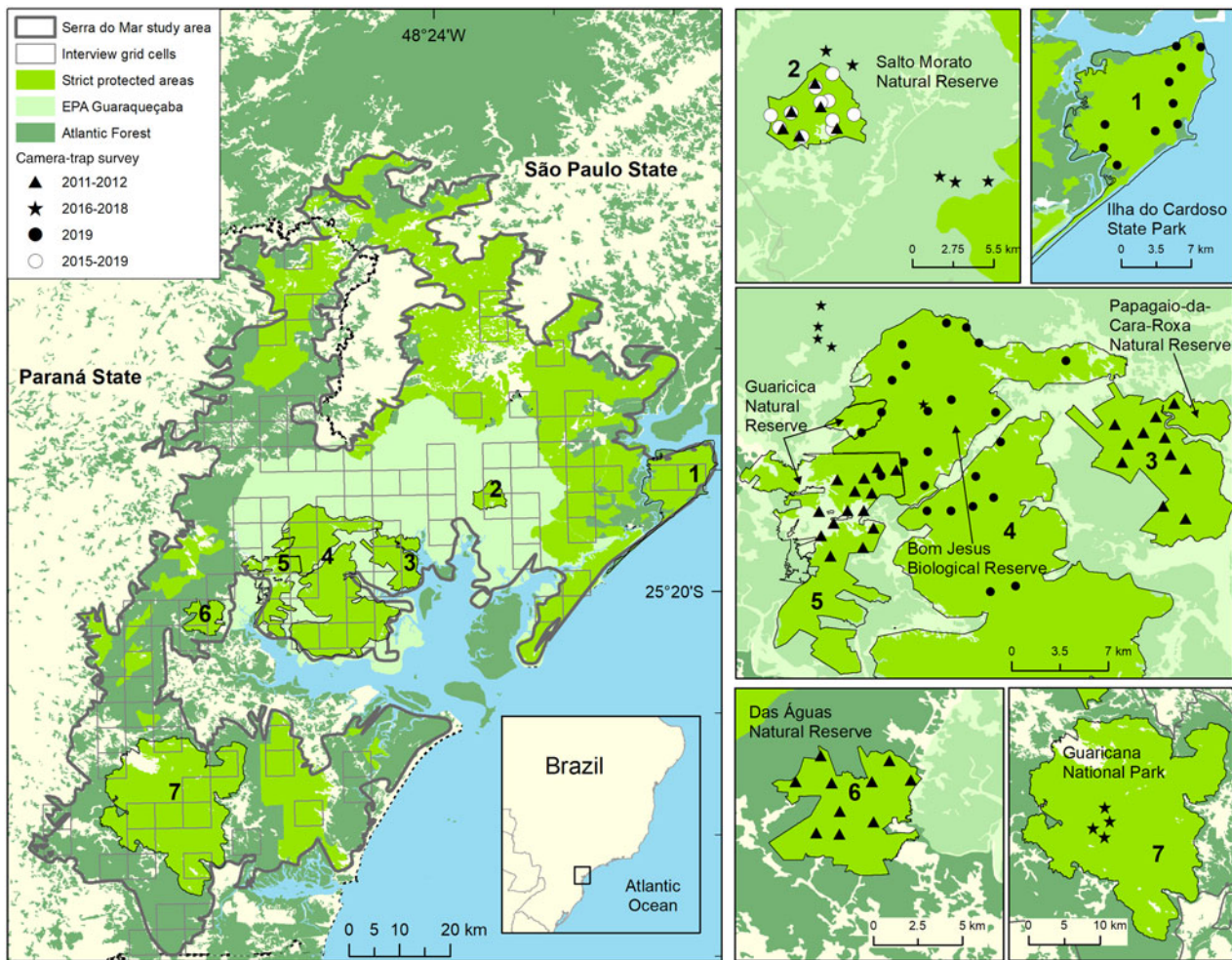


Fig. 1 Serra do Mar study area, with the grid cells where we conducted interviews and the locations of the camera-trap stations in seven protected areas. EPA, Environmental Protected Area.

2014). In 3,741 trap-days we recorded 23 species of mammals  $> 1$  kg. The only large mammal expected in this region that we did not record was the jaguar. However, local inhabitants reported to us that the jaguar was present in a mountainous area that was difficult to access.

To collect information on the presence of jaguars and other mammals in the entire Serra do Mar region in Paraná and southern São Paulo states (c. 6,500 km<sup>2</sup>), we carried out interview surveys during 2012–2017. We divided the area into 5 × 5 km grid cells and randomly selected 102 for surveys (Fig. 1, Supplementary Material 1). In 249 interviews we received at least one report of the potential presence of the jaguar in each of 24 grid cells (23.5% of the total surveyed; Fig. 2b).

During 2016–2018 we established 14 camera-trap stations (Fig. 1) for a total of 705 trap-days in three protected areas (Bom Jesus Biological Reserve, Guaricana National Park and Guaraqueçaba Environmental Protected Area) where informants had reported the occurrence of jaguars. In July 2018, we obtained two independent jaguar records (on different days) at one camera-trap station in a remote and

mountainous area of the Guaraqueçaba Environmental Protected Area (Fig. 1). The first record was an adult male, and the second the same adult male together with a female, exhibiting courtship behaviour (Plate 1).

In 2019 we established 32 camera-trap stations in Bom Jesus Biological Reserve and Ilha do Cardoso State Park (Fig. 1). In a total of 1,130 trap-days we obtained four records of jaguars: a previously unrecorded adult male and the male recorded in 2018, from four camera-trap stations in the northern mountainous portion of the Reserve.

During 2015–2019, the management of Salto Morato Private Nature Reserve carried out an annual mammal monitoring programme using 4–11 camera-trap stations (Fig. 1) for a total of 8,633 trap-days. In September 2018 they provided us with an image of the first record of a jaguar in the Reserve, which we identified as an additional individual of undetermined sex, and in 2019 they recorded a previously unrecorded female jaguar in the Reserve.

Overall during 2011–2019, 98 camera-trap stations operated for a total of 14,239 trap-days, with 76% in lowland forests at 0–200 m and 24% in montane forests at

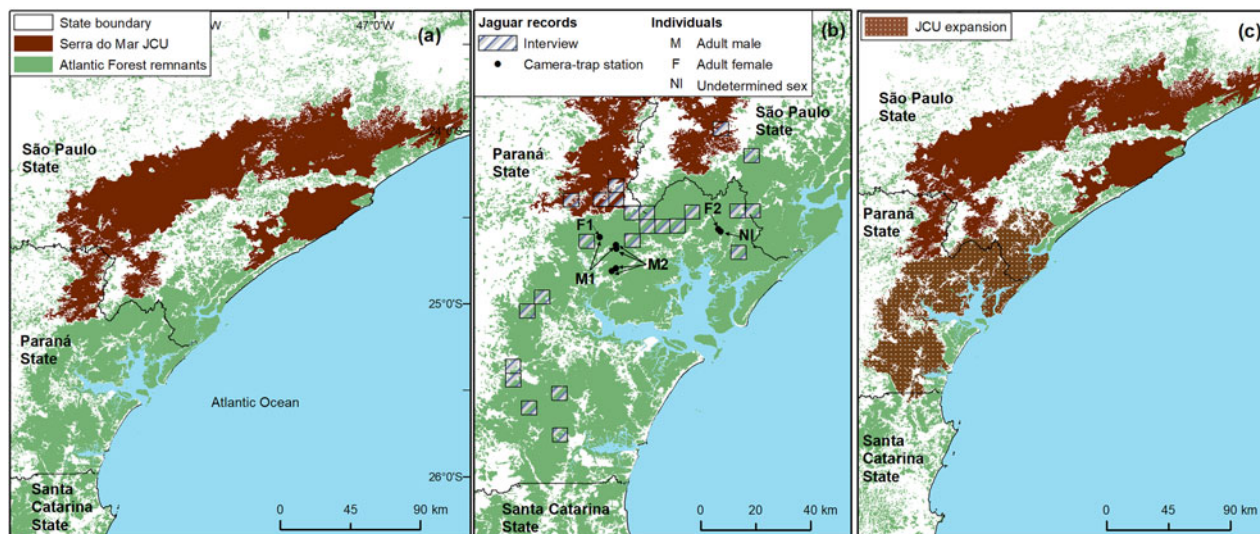


FIG. 2 (a) The jaguar conservation unit (JCU) of the Serra do Mar region (adapted from Paviolo et al., 2016, with a different forest shape file; Supplementary Material 2). (b) New jaguar *Panthera onca* records in the Serra do Mar (five individual jaguars: two males, two females and one of undetermined sex). (c) Our proposed southern expansion of the Serra do Mar jaguar conservation unit.



PLATE 1 The first photographic record of jaguars *Panthera onca* in the Serra do Mar region of the Atlantic Forest in Paraná State, Brazil (Fig. 1), showing two adult individuals, one male and one female, exhibiting courtship behaviour.

200–700 m. We obtained eight records of five individual jaguars (two males, two females and one of undetermined sex) at seven camera-trap stations (Fig. 2b) in montane forests. The presence of females and nearby males indicates the use of this area by jaguars is not occasional and that males

are monitoring the area in search of females. The low number of records relative to the high survey effort suggests a low abundance of jaguars, presumably taking refuge in these difficult-to-access montane areas as a result of historical and current hunting pressures in the region (Leite & Galvão, 2002; Mazzolli, 2009).

Our results have implications for jaguar conservation in the Atlantic Forest, because they modify the status of the area from unoccupied to occupied by the jaguar (Fig. 2a, c). Using an adaptation of previous methodology (Paviolo et al., 2016), the new jaguar records from camera traps result in an increase in the area of jaguar occupancy and area of jaguar potential occupancy (Supplementary Material 2) of 3,434 km<sup>2</sup> and 2,281 km<sup>2</sup>, respectively. This is a 9% increase in the area of jaguar occupancy in the Atlantic Forest and a 46.9% increase of jaguar occupancy in the Serra do Mar compared to the previously estimated areas of 37,825 km<sup>2</sup> and 7,315 km<sup>2</sup> (Paviolo et al., 2016), respectively. Inclusion of the information from interviews increases the area of occupancy by an additional 1,208 km<sup>2</sup>. The presence of males and females in the fragment, including evidence that individuals are breeding, makes it a priority area for jaguar conservation (i.e. a jaguar conservation unit; Supplementary Material 2). As this area is contiguous with the existing Serra do Mar jaguar conservation unit (Paviolo et al., 2016), we propose a southwards expansion of this unit by 5,715 km<sup>2</sup> (i.e. the areas of occupancy and potential occupancy; Supplementary Material 2), increasing the previously existing jaguar conservation unit of 13,547 km<sup>2</sup> to 19,262 km<sup>2</sup> and thus making it the largest priority area for jaguar conservation in the Atlantic Forest biome.

Our findings reinforce the importance of protected areas for jaguar conservation, including the need for investments

to curb poaching and to monitor the jaguar population throughout this region. With large-scale monitoring we would be better able to understand the patterns and process of jaguar population expansion/retraction over time and identify any potential human–jaguar conflicts that lead to jaguar deaths because of retaliation (Palmeira & Barrella, 2007). Such data are crucial for the identification of corridors and source population areas that require protection, and for conflict mitigation and conservation planning.

This enlarged jaguar conservation unit could serve as a vital source of individuals for the coastal forests further south. Although jaguars seem to be extinct in Santa Catarina state to the south (Mazzolli, 2009), our interview data suggest that the forested regions of this state, which are contiguous with those of Paraná state (Fig. 2), could be classified as an area of potential jaguar occupancy (Supplementary Material 2). We recommend that surveys are extended to Santa Catarina state to determine whether the presumed extinction of jaguars there represents another case of a false absence.

**Acknowledgements** We thank the institutions that supported this work (Fundação Florestal, Instituto Chico Mendes de Conservação da Biodiversidade, Sociedade de Pesquisa da Vida Selvagem, Fundação Grupo Boticário, Instituto de Água e Terra do Paraná); all protected area staff; local residents who helped us access areas to install camera traps (the Lamberg family and Genivaldo); all interviewees; and Marion L.B. Silva, Samuel Duleba and Ginessa Lemos for sharing the data from Reserva Natural Salto Morato. We received financial support from Fundação Grupo Boticário, The Rufford Foundation, WWF-Brazil and ABN-AMRO Bank. RF-C received a postdoctoral fellowship from Programa Nacional de Pós-Doutorado da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

**Author contributions** Study design and fieldwork: RF-C, BI, GSM; data analysis: RF-C, BI; writing: RF-C, BI, GSM, ELdAM-F.

**Conflicts of interest** None.

**Ethical standards** This research abided by the *Oryx* guidelines on ethical standards.

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