Muriqui House: conservation management to support the recovery of the northern muriqui *Brachyteles hypoxanthus* in Ibitipoca, Minas Gerais, Brazil

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Abstract Ensuring the demographic and genetic viability of small populations of threatened primates requires a range of management approaches. Here we describe a novel mixed in situ and ex situ management project that was developed to restore a population of the Critically Endangered northern muriqui *Brachyteles hypoxanthus*. This isolated population, located in Ibitipoca, Lima Duarte, Minas Gerais, Brazil, had declined to two adult males and would have gone extinct without intervention. A first attempt at in situ management in 2017 involved the translocation of a solitary female from another region, but this female did not associate or interact with the males and disappeared after 9 months. We thus initiated a second and ongoing ex situ management project that involved constructing a complex consisting of a large, open-air enclosure abutting a small patch of forest surrounded by an open area in the process of restoration, all of which is protected by electric fencing. The entire area within the fencing is called Muriqui House. The two Ibitipoca males and two solitary, wild females from another location were captured and released into the enclosed part of Muriqui House between March 2019 and January 2020 and into the forested part of Muriqui House in February 2020. The birth of an infant in this group in November 2020 and the acceptance by the group of a third female translocated from another area in January 2021 demonstrate the potential of this approach for the recovery of this isolated population, with positive implications for the conservation of the species.

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The destruction of tropical forests is one of the main threats to primate survival at both local and global scales (Butti et al., 2002; Estrada et al., 2017, 2018; Fernández et al., 2022). Habitat loss and fragmentation result in small, isolated populations that will become inviable in the near future (Shaffer, 1981; Brito, 2009). In these cases, management programmes involving translocations and reintroductions of individuals or groups are needed to establish the genetic and demographic variation necessary for populations to persist (Kierulff et al., 2007).

Here we describe a conservation management initiative for the northern muriqui *Brachyteles hypoxanthus*, a Critically Endangered primate endemic to the Atlantic Forest of south-eastern Brazil. Approximately 1,000 individuals are known to occur in 12 populations, only half of which comprise > 100 individuals (Strier et al., 2017; Melo et al., 2021). The other, smaller populations vary in size, with the smallest in the Mata dos Luna, a forest remnant of c. 40 ha at Ibitipoca in Lima Duarte, Minas Gerais, Brazil (Fig. 1).

In 2002 there were 10 individuals in a mixed-sex group in the northern muriqui population in the Ibitipoca forest (Oliveira, 2003; Nogueira et al., 2010). By 2015 only two adult males remained. Northern muriquis can be individually identified by their natural markings, and the Ibitipoca males were assigned unique codenames (BER-IB, LUN-IB) to distinguish them and their population of origin. The isolation of this population from other northern muriqui populations precluded any possibility of female recruitment without intervention. Thus, following the Brazilian National Action Plan for the Conservation of Muriquis (Jerusalinsky et al., 2011), we started a management project with both in situ and ex situ management components, to preserve what remained of the genetic diversity of this population.

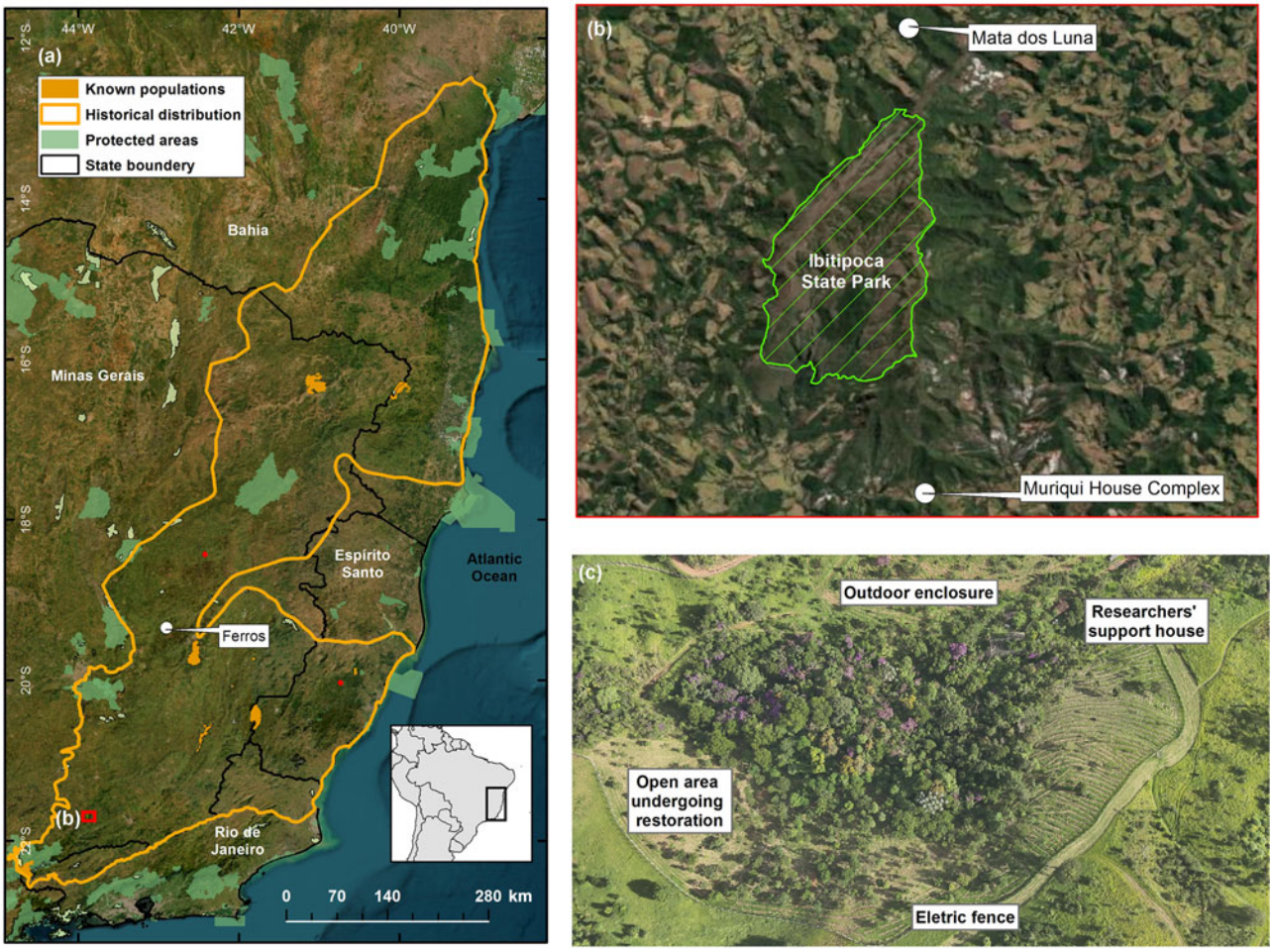

FIG. 1 (a) Historical distribution of the northern muriqui *Brachyteles hypoxanthus*, (b) location of the Muriqui House complex in Minas Gerais State, Brazil and Mato dos Luna in relation to Ibitipoca State Park, and (c) the forest included in the Muriqui House complex. Drone photo: Fabiano R. de Melo. (Readers of the printed journal are referred to the online article for a colour version of this figure.)

Northern muriquis typically live in multi-male, multi-female groups in which males are philopatric and females disperse from their natal groups prior to the onset of puberty (Strier & Ziegler, 2000; Strier et al., 2015). This information, along with many other insights about the demographics, diet and feeding, ranging and social and reproductive behaviour of muriquis, comes from the long-term Muriqui Project of Caratinga (Strier, 2021). Whenever appropriate we used this knowledge about wild northern muriquis to inform our conservation management decisions.

Females born in isolated populations that support only a single social group either remain in their natal groups, where they risk breeding with close relatives, or disperse into other forest fragments, where they spend their lives alone (Tabacow et al., 2021). Solitary females have been translocated into other small populations, where they successfully reproduced with resident males (Mendes et al., 2005; Tabacow et al., 2021). We initially employed a similar approach in the Ibitipoca population.

In January 2017 we translocated a solitary female (ESM-FE) from a forest fragment in Ferros, Minas Gerais, 285 km north of the Mata dos Luna. We initially released the female into a 5 × 3 m, 5 m high, outdoor wire mesh enclosure constructed for this purpose in a clearing within the forested home range of the two males. The intention was to give her time to habituate to her new location and to permit observers to monitor her health and adaptation after the translocation. We also hoped that her presence would attract the males and subsequently facilitate her integration into their group.

We released her 3 days later, but she did not interact with the males, nor did they approach or follow her. She travelled instead to a distant patch of forest, where observers were able to follow her movements until she disappeared 9 months later.

It is possible that ESM-FE's history of living alone for at least the previous 2 years, combined with the absence of female associates for the two Ibitipoca males over at least 8 years, could have inhibited them from engaging in

PLATE 1 (a) An adult female (ECO-S) northern muriqui *Brachyteles hypoxanthus* with her infant, ELI-IB, the first northern muriqui born in the Muriqui House complex (Fig. 1). Photo: Fred Crema. (b) Muriqui House, showing the enclosure and part of the surrounding fenced forest patch. Drone photo: Fabiano R. de Melo.

social interactions, as has occurred in other populations in which solitary females were translocated and released into established mixed-sex groups (Tabacow et al., 2021). We concluded that more controlled conditions of captivity would be necessary to increase the opportunities for social interactions that would lead to the formation of a group with reproductive potential.

We implemented a new approach, bringing the animals into an open-air 20 × 8 m, 9 m high, wire enclosure constructed adjacent to a 1.84 ha patch of native secondary forest vegetation 11 km from Mata dos Luna. The enclosure, the adjacent forested area and the surrounding open area bounded by electric fencing form a complex that we named Muriqui House.

The enclosure part of Muriqui House has two sections separated by a wire mesh window and wooden door that can be opened or closed whenever it is necessary to separate any of the animals. There are hatches that open into each section for offering food and four platforms for resting. Within this enclosure a variety of wooden supports and some remnant native trees permit the northern muriquis to engage in their typical suspensory mode of locomotion. In addition, there are sheltered areas that provide protection from poor weather conditions. At each end there are passages that can be opened to permit access to the forest adjacent to the enclosure (Plate 1).

A total of 146 native plant species have been identified in this forested area within the Muriqui House complex, 30 of which are known to be eaten by wild northern muriquis elsewhere (Strier, 1991). Four supplemental feeding platforms (1 × 1 m) were constructed 3 m above the forest floor. The entire Muriqui House complex (enclosure plus forest and an open area under restoration) is surrounded by 3.83 ha of cleared habitat, where 2,500 plants of various native species have been planted for vegetation restoration. The perimeter is surrounded by nets and electrical wires to protect the northern muriquis from predators and to prevent escapes (Fig. 1).

We captured the two adult males, BER-IB and LUN-IB, and released them into the Muriqui House enclosure in May and August 2019, respectively, where they joined a solitary female (ECO-S) known to be c. 9 years of age. She had been translocated from the area surrounding the Reserva Particular do Patrimônio Natural (Private Natural Heritage Reserve) Mata do Sossego in Simonésia, Minas Gerais, Brazil, and we released her into the enclosure in March 2019 (Tabacow et al., 2021). We translocated a second solitary female (SOC-S), estimated to be c. 20 years of age, from the same area as ECO-S and introduced her into the enclosure in October 2019, completing what became the four-member founder group.

We carried out all captures in accordance with previous recommendations (Oliveira et al., 2020; Teixeira et al., 2022). Veterinarians monitored the animals closely following pre-established protocols for sedation during capture through to their transport and release into the enclosure (Valença-Montenegro et al., 2021).

From the outset we provisioned the occupants of Muriqui House with a diet that resembled the leaves and fruits that northern muriquis are known to eat in the wild, supplemented with flowers, nectar and seeds (Strier, 1991). We experimented by adjusting food quantities and substituting items whilst striving to maintain an appropriate nutritional balance rich in fibre, protein and carbohydrates. The acceptance of the northern muriquis of green, leafy vegetables, including collard greens, broccoli and cabbage, was important as these items contributed significant quantities of fibre to their diets. We developed a diet composed of four menus offered on alternating days, with the food provided at different times and locations in the enclosure to

stimulate natural foraging practices of the northern muriqui. We offered leaves on all menus. We mostly offered foods high in protein, energy, fat, vitamins and minerals in the morning, and mostly offered vegetables in the afternoons. The northern muriquis also supplemented their diets by sampling the plants growing in the enclosure.

We used environmental enrichments to maintain the health, quality of life and behavioural repertoire of the northern muriquis. These enrichments included providing natural food items for their menus, which we collected from the surrounding forests, constructing support structures to encourage their natural suspensory locomotion, and attaching provisioned fruit below branches to stimulate natural foraging postures (Iurck et al., 2013).

Throughout daylight hours, trained observers monitored the northern muriquis, collecting behavioural data using scan and focal animal samples following the ethogram and sampling protocols established from long-term field studies of the behaviour and ecology of a wild northern muriqui population (Strier, 1999). The northern muriquis engaged in affiliative behaviours and vocalizations typical of this species in the wild, including extended, intense affiliative embracing between the two males. Thus, as anticipated, the enclosure facilitated social interactions not only amongst the two males, who were already familiar with one another, but also amongst the females and between the males and females. During November 2019–February 2020 we observed BER-IB copulating twice with each of the two females.

In February 2020 we released the northern muriquis into the forested area of the Muriqui House complex, where we maintained their provisioned diet but where they also foraged on naturally occurring plants. Once released into the forest of Muriqui House we observed BER-IB copulating with ECO-S during 8–19 March 2020. ECO-S gave birth to her first infant, ELI-IB, on 3 November 2020, 229 days after her last observed copulation (Plate 1). This is longer than the median 216 days gestation length (range: 214.5–218.5 days) described from faecal steroid analyses of a larger sample of wild females (Strier & Ziegler, 1997), suggesting that at least one subsequent copulation, which was responsible for the conception, had been missed by observers.

On 12 November 2020 we translocated a third solitary female (NEN-PNC), estimated to be c. 5 years of age, from the Caparaó region, in Espírito Santo State, Brazil, where one of the largest northern muriqui populations is located (Clyvia et al., 2020). As with the other northern muriquis, we initially released NEN-PNC into the enclosure to acclimatize, and on 18 January 2021 we released her into the forested part of the Muriqui House complex. Consistent with the pattern of social integration observed amongst immigrant female northern muriquis in the wild (Strier et al., 2015), NEN-PNC initially associated with the males, avoided the females and engaged in playful interactions with the infant. There are now six northern muriquis in this newly established group.

There are many difficulties intrinsic to a project of this size, such as the availability of specialized personnel and the construction and maintenance of structures. There are also challenges inherent in artificially manipulating the formation of a group of animals with a complex social system. Nonetheless, we have shown the feasibility of managing male northern muriquis from the same natal group with females from different locations to establish a new social group with demonstrated reproductive potential. Our success was based on promoting social interactions consistent with the natural behaviour of the species in a setting that permits us to monitor their behaviour, nutrition and health. The consolidation of this new social group offers hope for the repopulation of northern muriquis in the forests of Ibitipoca and for the maintenance of their genetic diversity. The experiences obtained from this approach could also be useful for similar initiatives for the conservation of other reduced populations of northern muriquis and other primates.

Author contributions Study design: FRdM, FPT, MSN, MV-M, LSM, KBS, LJ; fieldwork: FRdM, FPT, PMP, MSN, EPTT, DS-T; data analysis, writing: FRdM, FPT, PMP, MSN, EPTT, DS-T, MV-M, KBS, LJ; funding acquisition: FRdM, FPT, MSN, KBS.

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Conflicts of interest None.

Ethical standards This research complied with all ethical requirements in Brazil (Process SISBIO License no. 64.438-6; CEUA UFMG 163/2020) and abided by the *Oryx* guidelines on ethical standards.

Data availability Data available upon request to the authors.

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