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PERSPECTIVES AND NOTES

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End of the line for the golden lion tamarin? A single road threatens 30 years of conservation efforts

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Abstract

Roads have a myriad of negative effects on biodiversity, ultimately threatening the persistence of populations. In this Perspective we call attention to an extreme example, where the entire current geographic range of the endangered golden lion tamarin (*Leontopithecus rosalia*, GLT) is bisected by a major highway that is being widened to four lanes. We believe that the planned mitigation actions are not enough to reduce the expected increase of barrier effects and road mortality. These impacts may lead to a sequence of cascading effects that could jeopardize the conservation actions that prevented the extinction of GLTs three decades ago. We identify specific road sections along the highway and accompanying paved roads in the region that if equipped with tailored over passages would greatly reduce the road

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barrier effects. We also highlight areas where reforestation efforts could be extended in order to help reestablishing the connectivity between GLT habitat areas. We suggest that the working group integrating key decision makers and stakeholders, including the Non-governmental organization leading the conservation efforts, partner universities, national road and environmental agencies, and the road construction company, to implement and to monitor the complementary road passages to improve connectivity of GLT habitat, and consequently to ensure the species' survival.

KEYWORDS

endangered species, habitat fragmentation, landscape connectivity, mitigation prioritization, roadkill

1 | INTRODUCTION

Habitat loss due to anthropogenic activities is a major cause of population decline and extinction of species (Bogoni, Pires, Graipel, Peroni, & Peres, 2018; Haddad et al., 2015). One of the negative effects of habitat loss is the reduction in connectivity between habitat patches as these become smaller and more isolated, limiting species access to key resources such as food or reproductive partners (Fahrig & Merriam, 1994; Hanski, 1998; Kremen & Merenlender, 2018). Transportation infrastructure—particularly roads—is expanding worldwide, bisecting landscapes even in the most remote regions (Ibisch et al., 2016). Although linear infrastructure may cause minimal direct habitat loss, it creates barriers that may reduce or impede species movements either because they represent physical obstacles or due to species' avoidance behavior toward them (Chen & Koprowski, 2016; Marsh, Milam, Gorham, & Beckman, 2005). In addition, vehicle traffic and its emissions (i.e., noise and pollution) can also be a strong deterrent for animal movement, and animal-vehicle collisions may contribute to the significant decline of local populations (Baxter-Gilbert, Riley, Neufeld, Litzgus, & Lesbarrères, 2015; González-Suárez, Zanchetta Ferreira, & Grilo, 2018; Loss, Will, & Marra, 2014).

It is crucial for the persistence of wildlife populations to guarantee the connectivity among habitat patches in order to provide the minimum area requirements, particularly for species that have a Conservation Concern status (Rudnick et al. 2012). In most situations, this involves increasing the road permeability for animal movement. Therefore, all stakeholders involved in road planning, construction, and management—including road agencies and enterprises—are key players in conservation practice. Such impacts are expected to be even more significant for species with restricted distributions inhabiting fragmented landscapes bisected by roads. Here, we call attention to a real threat to the future of the golden lion tamarin (*Leontopithecus rosalia*, GLT). This small (<600 g) arboreal primate is endemic to a small region of the Brazilian Atlantic Forest within the State of Rio de Janeiro (Kierulff, Rylands, & de Oliveira, 2008; see Figure 1; Culot et al., 2019). This species is one example of many, particularly primates, that are under threat due to the synergistic impacts of habitat loss and fragmentation due to the proliferation of transportation infrastructures (Estrada et al., 2017).

2 | INHABITING A PATCHWORK OF REMNANTS AND ROADS

The Atlantic Forest is a biodiversity hotspot and one of the most endangered ecoregions worldwide (Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000). Currently, ~12% of its original vegetation cover remains, most of which consists of forest patches smaller than 50 ha (Ribeiro, Metzger, Martensen, Ponzoni, & Hirota, 2009). In fact, the GLT is classified as Endangered by the IUCN because of population reduction and habitat loss that have taken place over centuries in the Atlantic Forest (Grativol, Ballou, & Fleischer, 2001; Kierulff et al., 2008, 2012; Moraes et al., 2017; Ribeiro et al., 2009; Valle, Francelino, Hardt, & Pinheiro, 2018). According to our estimates, the area occupied by the GLT suffered a continuous decline since European colonization (16th century) and today it probably represents ~0.4% of its original area (see Supporting Information, Figure S1.1 in Data S1). Moreover, most of the forest patches within GLT range are small and isolated. For example, one third of the native forest in our survey area consists of a single forest block of ~7,500 ha in the northern region. However, the mean forest patch size (after removing the largest one) is less than 1 ha (Figure 1; Figure S2.1A in Data S2). Isolation and the small sizes of forest patches reduce the functional connectivity among forest patches (Figure S2.1b,c). Also, in this region 67% of the forest is less than 100 m from edges with nonforest matrices,

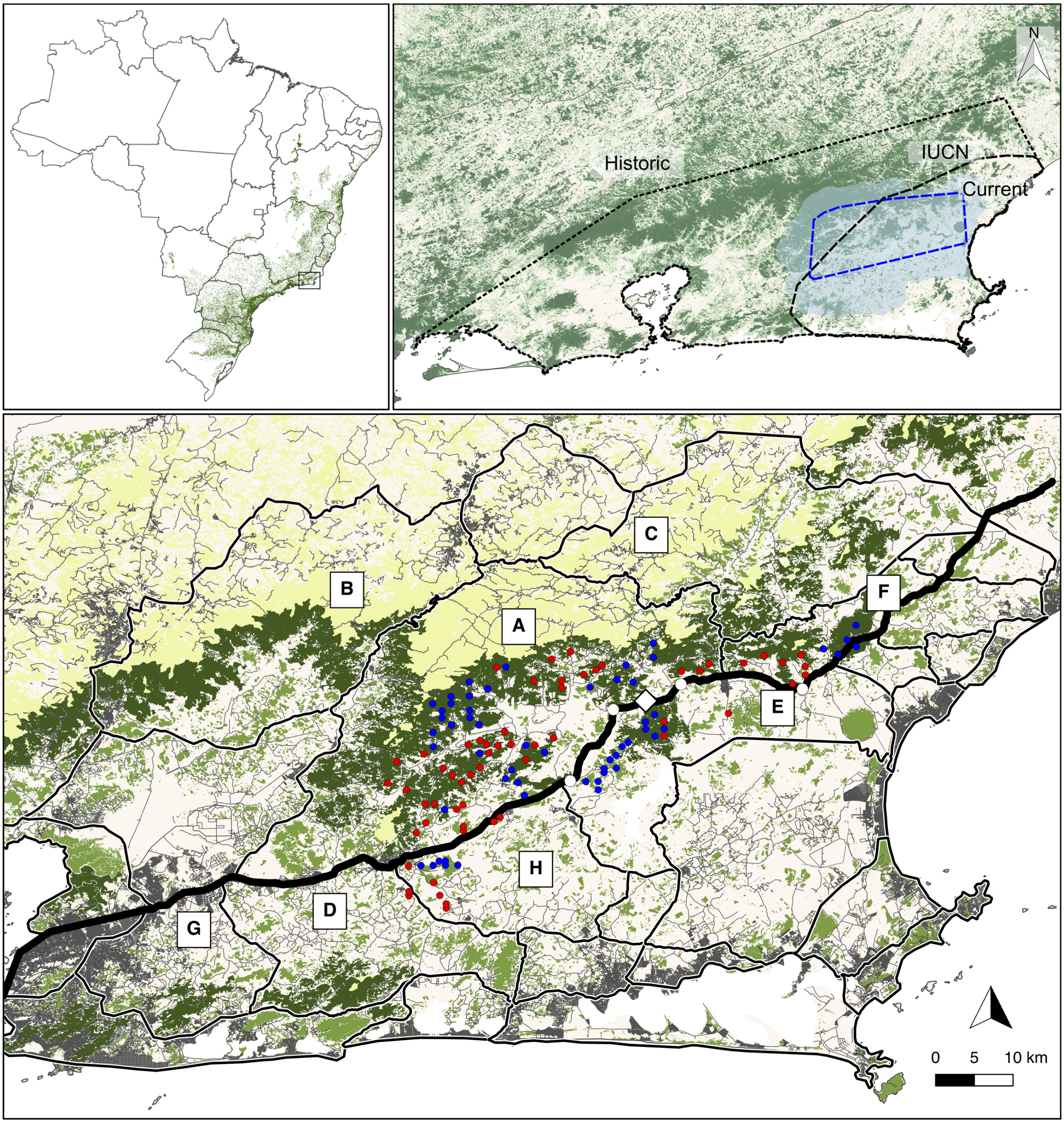

FIGURE 1 Upper left: distribution of Atlantic Forest patches in Brazil. Upper right: the distribution of golden lion tamarin for three timeframes: "Historic" (1800—early 1900); "IUCN," ca. year 2008 (IUCN, Kierulff et al., 2008); and "current" range (Ruiz-Miranda et al., 2019). Atlantic Forest patches are shown in green. Light green shading is the S. João river basin, commonly used as the study area for the golden lion tamarin research. Bottom: area that we suggest to be managed toward increasing the landscape and road permeability, and which includes part of the historic range and other good quality habitat patches. Green is Atlantic Forest, with dark green representing larger continuous patches, and yellow areas representing forest areas above 700 m (GLTs are rarely seen above 550–700 m). Black lines are paved roads, the wider one is the BR-101, the most important road in the region, and in grey are unpaved roads and urban areas. Road-bounded polygons are identified with capital letters (A to H), according to the amount of forest within them. White dots along BR-101 are prospective locations of wildlife overpasses (circles are canopy passages and square is the vegetated overpass), proposed after a process of discussion between different stakeholders, including government, highway enterprise, and Non-governmental organization. Blue/red dots indicate forest patches where GLT was detected/not detected in the AMLD survey performed in 2014 (see Ruiz-Miranda et al., 2019)

and this proportion increases to 90% when considering a distance up to 250 m from forest edges (Figure S2.1d). The high prevalence of forest edge increases the exposure of GLTs to other threats, including attacks by domestic dogs and zoonosis (Kierulff & Oliveira, 1994; Lessa, Corrêa Seabra Guimarães, de Godoy Bergallo, Cunha, & Vieira, 2016).

Furthermore, the area of occurrence of the GLT is located between the city of Rio de Janeiro and Brazil's most important region for oil extraction. This area is experiencing accelerated urban and industrial growth, factors that result in expansion of linear infrastructures including railroads, pipelines, and power lines, all of which fragment the forest. More worryingly, the whole geographic range of the GLT is traversed by a network of roads (Figure 1), many of which are paved and carry significant traffic volumes, thus potentially increasing the isolation of habitat areas and risk of mortality caused by vehicles. The most significant road is a major highway (BR-101), used by an average of 18,000 vehicles per day (DNIT, 2017). This road bisects the entire GLT distribution area and is known to be a strong barrier to GLT routine and dispersal movements (Mickelberg, 2011; Moraes et al., 2018), and a cause of mortality for individuals venturing to cross the road (pers. obs.). The BR-101 highway isolates important areas of native forest, including the two Biological Reserves, from the rest of the metapopulation (Ruiz-Miranda et al., 2019). These reserves are key to the conservation of GLTs because they are the largest legally protected areas in the region and their populations contain important genetic diversity and private alleles (Grativol et al., 2001; Moraes et al., 2017; Moraes, Ruiz-Miranda, et al., 2018).

This highway is currently being widened to four lanes across the GLT distribution area. This widening will result in the effective disturbed area (road lanes and verges) increasing from ~15 to 55 m. Moreover, Jersey barriers will be implemented in several stretches of the highway, which may further difficult the movement across the highway. Overall, the duplication of BR-101 is expected to significantly increase its daily traffic volume and that of surrounding roads. A wider highway with Jersey barriers and higher traffic volumes is likely to be a stronger barrier and/or mortality threat for this arboreal species.

3 | REACHING THE TIPPING POINT?

Some aspects of GLT biology make it a difficult species to manage in a fragmented landscape. GLTs typically live in small family groups of 4–6 adults that occupy territories larger (average 50 ha) than expected by its body size (Hankerson & Dietz, 2014). This territory requirements render mean local density from 0.05 to 0.10 adults per ha (Hankerson & Dietz, 2014). Also, the GLT has a generation time of ca. 6–7 years (Holst et al., 2006), and although individuals reach sexual maturity before 2 years, successful reproduction is usually achieved only when they reach 4 years (Dietz, Baker, & Miglioretti, 1994). Both sexes disperse, but female success is based upon finding empty forest areas, whereas male success depends on coalitions to oust resident males (Romano, Martins, & Ruiz-Miranda, 2019). The short reproductive life span coupled with a small population size makes this species highly vulnerable to stochastic events (Shaffer & Samson 1985). As such, most road-bounded polygons (see Figure 1) are unable to sustain viable populations of GLTs in the long term. For GLT populations to persist, individuals will have to cross paved roads frequently, and particularly the BR-101. Hence, if forest patches are not functionally connected, within and across road-bounded polygons, even GLT subpopulations inhabiting the larger forest areas may become severely reduced (Moraes et al., 2017; Ruiz-Miranda et al., 2019).

Field observations from capture-mark-recapture and tracking data, suggest that GLTs can cross ~100 m of pasture between forest patches, but they rarely cross greater distances, and seldom the current highway width (Mickelberg, 2011). Furthermore, increasing traffic volume throughout the region may discourage road-crossing movements, particularly north–south displacements across the BR-101. Hence, the impacts of BR-101 together with the loss of habitat may lead to a sequence of cascading effects that can jeopardize historic conservation actions that successfully recovered the species from imminent extinction (Kierulff et al., 2012; Ruiz-Miranda et al., 2019).

4 | THE ROAD AHEAD: BRIDGING THE GAPS

As a result of 7 years of discussions and negotiations among key stakeholders—Autopista Fluminense (the highway construction company), the national agency for infrastructure and transportation (ANTT), national environmental agencies including ICMBio and IBAMA, the local Non-governmental organizations (e.g., the Golden Lion Tamarin Association, AMLD), and local universities (e.g., northern Rio de Janeiro State University, UENF)—some important mitigation measures are currently being considered. The most significant of which are the construction of one vegetated wildlife overpass (possibly two), underpasses and canopy bridges. The overpasses will connect the road-bounded polygons A and E (Figure 1). While these structures will certainly play an important role in mitigating the effects of BR-101, we believe that other locations to install road passages should also be considered. In view of the amount of forest area available within the road-bounded polygons (Figure 1), priority should also be given to guaranteeing the connectivity between polygons A-D and A-H (bisected by BR-101). Other important links to be (re)established are those between polygons A-B, A-C, A-F, and C-F on the north side of BR-101, and D-G, D-H, and E-H on the south side (Figure 1, bottom). We note that such mitigation on secondary roads may be achieved by tying bamboo poles to canopies of trees on either side of the road. However, for the wider BR-101, dedicated over-passages must be considered. We further suggest that ongoing forest restoration efforts be extended to facilitate movement of GLTs within the road-bounded polygons D and G (Figure 1).

We suggest that the working group integrating the abovementioned key stakeholders identify the exact locations to implement the additional arboreal passages necessary to improve the connectivity for the GLT, as well to monitor their effectiveness. This involves collecting tracking information in order to ascertain if individuals can effectively move among habitat areas separated by the different types of paved roads, before and after the installation of mitigation measures. A highly qualified group of researchers to carry out this work, already exist, led by the AMLD. However, they do not have the necessary resources (including budget) to get sound empirical data animal movement. Thus, a research fund could be created, with contributions from the government and the highway company, and managed by the environmental agency, to support the collection of movement data and GLT population parameters. This is different from the usual requirement that the construction company do their own in-house hiring and supervising of monitoring data, and thus will provide independent and sound information, crucial for decision-making.

We anticipate that the conservation practices here suggested, namely installing passages in more sites across the road network and the monitoring process, might have a positive spillover effect in other sections of BR-101 as well as in other road networks in Brazil. For example, BR-101 also fragments the habitat of two other threatened arboreal primates within the Atlantic Forest, the golden-headed lion tamarin (*Leontopithecus chrysomelas*) and Wied's marmoset (*Callithrix kuhlii*), and is known to hinder inter-population gene flow and to reduce habitat suitability for these species (Guy et al., 2016; Moraes et al., 2018). These measures could also benefit other endangered forest-dwelling species occurring in the region, including threatened mammals as the maned sloth (*Bradypus torquatus*), and birds, including Salvadori's antwren (*Myrmotherula minor*) and the banded cotinga (*Cotinga maculata*). Above all, a proper mitigation of the BR-101 may finally raise the awareness that road planning requires a deep understanding of the biodiversity that is to be affected, and that Road Ecology studies should be integrated in the transportation planning process, and more generally in strategic environmental assessments throughout developing countries (Ascensão et al., 2018).

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

F.A., B.B.N., C.R.R.-M., M.C.R. conceived the study; F.A., B.N., A.M.M., B.R.A. organized spatial data; A.M.M., B.R.A., M.M.M.-Jr., A.F.M., A.O., E.M., J.H.R., L.P.F., J.M.D., C.R.M.-M. contributed with data and expert knowledge; F.A., B.B.N. performed the analysis; F.A., B.B.N. wrote the first draft and all authors contributed with interpreting, discussing and writing the final version.

DATA ACCESSIBILITY

All data and code used in this study in freely available at the GitHub repository https://github.com/LEEClab/roads_and_connectivity_for_GoldenLionTamarins.

ETHICS STATEMENT

Research was not conducted that would have required approval.

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REFERENCES

Ascensão, F., Fahrig, L., Clevenger, A. P., Corlett, R. T., Jaeger, J. A. G., Laurance, W. F., & Pereira, H. M. (2018). Environmental challenges for the belt and road initiative. *Nature Sustainability*, *1*, 206–209.

Baxter-Gilbert, J. H., Riley, J. L., Neufeld, C. J. H., Litzgus, J. D., & Lesbarrères, D. (2015). Road mortality potentially responsible for billions of pollinating insect deaths annually. *Journal of Insect Conservation*, *19*, 1029–1035.

Bogoni, J. A., Pires, J. S. R., Graipel, M. E., Peroni, N., & Peres, C. A. (2018). Wish you were here: How defaunated is the Atlantic Forest biome of its medium- to large-bodied mammal fauna? *PLoS One*, *13*, e0204515.

Chen, H. L., & Koprowski, J. L. (2016). Barrier effects of roads on an endangered forest obligate: Influences of traffic, road edges, and gaps. *Biological Conservation*, *199*, 33–40.

Culot, L., Pereira, L. A., Agostini, I., de Almeida, M. A. B., Alves, R. S. C., Aximoff, I., … Galetti, M. (2019). ATLANTIC-PRIMATES: A dataset of communities and occurrences of primates in the Atlantic forests of South America. *Ecology*, *100*, e02525.

Dietz, J. M., Baker, A. J., & Miglioretti, D. (1994). Seasonal variation in reproduction, juvenile growth, and adult body mass in golden lion tamarins (Leontopithecus rosalia). *American Journal of Primatology*, *34*, 115–132.

DNIT. (2017). Pesquisa Nacional de Tráfego.

Estrada, A., Garber, P. A., Rylands, A. B., Roos, C., Fernandez-Duque, E., Fiore, A. D., … Li, B. (2017). Impending extinction crisis of the world's primates: Why primates matter. *Science Advances*, *3*, e1600946.

Fahrig, L., & Merriam, G. (1994). Conservation of fragmented populations. *Conservation Biology*, *8*, 50–59.

González-Suárez, M., Zanchetta Ferreira, F., & Grilo, C. (2018). Spatial and species-level predictions of road mortality risk using trait data. *Global Ecology and Biogeography*, *27*, 1093–1105.

Grativol, A. D., Ballou, J. D., & Fleischer, R. C. (2001). Microsatellite variation within and among recently fragmented populations of the golden lion tamarin (*Leontopithecus rosalia*). *Conservation Genetics*, *2*, 1–9.

Guy, C., Cassano, C. R., Cazarre, L., Vleeschouwer De, K. M., Kierulff, M. C. M., Neves, L. G., … Raboy, B. E. (2016). Evaluating landscape suitability for Golden-headed lion Tamarins (*Leontopithecus chrysomelas*) and Wied's black tufted-ear marmosets (*Callithrix kuhlii*) in the Bahian Atlantic Forest. *Tropical Conservation Science*, *9*, 735–757.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., … Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, *1*, e1500052.

Hankerson, S. J., & Dietz, J. M. (2014). Predation rate and future reproductive potential explain home range size in golden lion tamarins. *Animal Behaviour*, *96*, 87–95.

Hanski, I. (1998). Metapopulation dynamics. *Nature*, *396*, 41–49.

Holst, B., Medici, E. P., Marino-Filho, O. J., Kleiman, D., Leus, K., Pissinatti, A., … Raboy, B. (2006). *Lion tamarin population and habitat viability assessment workshop 2005, final report*. Apple Valley, MN: UCN/SSC Conservation Breeding Specialist Group.

Ibisch, P. L., Hoffmann, M. T., Kreft, S., Pe'er, G., Kati, V., Biber-Freudenberger, L., et al. (2016). A global map of roadless areas and their conservation status. *Science*, *354*, 1423–1427.

Kierulff, M. C. M., & Oliveira, P. d. P. (1994). Habitat preservation and the translocation of threatened groups of golden lion tamarins, *Leontopithecus rosalia*. *Neotropical Primates*, *2*, 15–18.

Kierulff, M. C. M., Ruiz-Miranda, C. R., Procópio Oliveira, P., Beck, B. B., Martins, A., Dietz, J. M., … Baker, A. J. (2012). The Golden lion tamarin *Leontopithecus rosalia*: A conservation success story. *International Zoo Yearbook*, *46*, 36–45.

Kierulff, M. C. M., Rylands, A. B., & de Oliveira, M. M. (2008). *Leontopithecus rosalia. The IUCN red list of threatened species 2008*. e.T11506A3287321. https://doi.org/10.2305/IUCN.UK.2008.RLTS.T11506A3287321.en

Kremen, C., & Merenlender, A. M. (2018). Landscapes that work for biodiversity and people. *Science*, *362*, eaau6020.

Lessa, I., Corrêa Seabra Guimarães, T., de Godoy Bergallo, H., Cunha, A. & M. Vieira, E. (2016). Domestic dogs in protected areas: A threat to Brazilian mammals? *Natureza & Conservação*, *14*, 46–56.

Loss, S. R., Will, T., & Marra, P. P. (2014). Estimation of bird-vehicle collision mortality on U.S. roads. *The Journal of Wildlife Management*, *78*, 763–771.

Marsh, D. M., Milam, G. S., Gorham, N. P., & Beckman, N. G. (2005). Forest roads as partial barriers to terrestrial salamander movement. *Conservation Biology*, *19*, 2004–2008.

Mickelberg, J. L. (2011). *Understanding and managing isolation in a fragmented population of Golden lion Tamarins, Leontopithecus rosalia.* (Ph.D). George Mason University, Virginia.

Moraes, A. M., Grativol, A. D., De Vleeschouwer, K. M., Ruiz-Miranda, C. R., Raboy, B. E., Oliveira, L. C., … Galbusera, P. H. A. (2018). Population genetic structure of an endangered endemic primate (*Leontopithecus chrysomelas*) in a highly fragmented Atlantic coastal rain Forest. *Folia Primatologica*, *89*, 365–381.

Moraes, A. M., Ruiz-Miranda, C. R., Galetti, P. M., Jr., Niebuhr, B. B., Alexandre, B. R., Muylaert, R. L., … Ribeiro, M. C. (2018). Landscape resistance influences effective dispersal of endangered golden lion tamarins within the Atlantic Forest. *Biological Conservation*, *224*, 178–187.

Moraes, A. M., Ruiz-Miranda, C. R., Ribeiro, M. C., Grativol, A. D., Carvalho, C. d. S., Dietz, J. M., … Galetti, P. M. (2017). Temporal genetic dynamics of reintroduced and translocated populations of the endangered golden lion tamarin (*Leontopithecus rosalia*). *Conservation Genetics*, *18*, 995–1009.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*, 853–858.

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., & Hirota, M. M. (2009). The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, *142*, 1141–1153.

Romano, V., Martins, A. F., & Ruiz-Miranda, C. R. (2019). Unraveling the dispersal patterns and the social drivers of natal emigration of a cooperative breeding mammal, the golden lion tamarin. *American Journal of Primatology*, *81*, e22959.

Rudnick, D., Ryan, S. J., Beier, P., Cushman, S. A., Dieffenbach, F., Epps, C., … Kintsch, J. (2012). *The role of landscape connectivity in planning and implementing conservation and restoration priorities*. Issues in Ecology. Report No. 16. Washington, DC: Ecological Society of America.

Ruiz-Miranda, C.R., Marçio M. de Morais Jr., Dietz, L.A., Alexandre, B.R., Martins, A.F., Ferraz, L.P., … Dietz, J. M. (2019). Estimating population sizes to evaluate progress in conservation of endangered golden lion tamarins (*Leontopithecus rosalia*). *PLoS One*, e0216664, *14*.

Shaffer, M. L., & Samson, F. B. (1985). Population size and extinction: A note on determining critical population sizes. *The American Naturalist*, *125*, 144–152.

Valle, I. C., Francelino, M. R., Hardt, E., & Pinheiro, H. S. K. (2018). Landscape indicators of the success of protected areas on habitat recovery for the Golden lion Tamarin (*Leontopithecus rosalia*). *Ecoscience*, *25*, 61–69.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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