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### Research Letters

## Impacts of mining activities on the potential geographic distribution of eastern Brazil mountaintop endemic species

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### ABSTRACT

Mining causes profound impacts on biodiversity. In Brazil, mining pressure is intense, especially in highly biodiverse regions such as the Espinhaço range. We analyzed the direct and indirect effects of mining on the potential geographic range of 32 anuran and eight bird species endemic to the eastern Brazil mountaintops. We also assessed the mining impacts on the local biodiversity rate of both species groups. Currently, 36.44% and 28.80% of the median potential distribution of the anuran and bird species, respectively, are affected directly or indirectly by mining. More than half of the range for eight anuran species and more than 40% of two birds species's ranges are influenced by this anthropogenic activity. Regions with suitable environmental characteristics for more than one species are highly affected by mining: 67% of the pixels that are suitable for 16 species (2109 km<sup>2</sup>) are currently impacted by mining. These results indicate that mining activities present a considerable threat to both anurans and birds endemic of the eastern Brazil mountaintops. We discuss many aspects related to the loss of potential habitat for these species, and call for management strategies to avert the ongoing wave of mining impacts.

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### Introduction

The depletion of mineral reserves and consumption are the drivers of the rush for mineral extraction. The mining pressure is especially intense in developing countries, such as Brazil, whose economy is largely based on commodity exports. Being the second world's largest mineral producer (IBRAM, 2012), the mining sector has considerable economic and political influence in Brazil (Garcia

et al., 2017). Although recent environmental disasters have demonstrated the vulnerability of the Brazilian environmental impact assessments and mineral extraction licensing processes, proposed changes in Brazilian mining legislation aim to facilitate mineral extraction (El Bizri et al., 2016; Fernandes et al., 2016). It has been argued that the development of widespread mining and dams in Brazil risks damaging its environmental conservation credentials (Ferreira et al., 2014). Moreover, Brazilian Government expects an increase of mineral production by 2030 (Brasil, 2010) which might further increase environmental impacts on biodiversity and ecosystem services provision.

We focus attention on the impacts of mining activities on species in a region where mineral extraction is one of the most important Brazilian economic activities: the eastern Brazil mountaintops.

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This region encompasses the Espinhaço range, a rich and diverse mountain range dominated by the rupestrian grasslands, an ecosystem that occurs on quartzitic or ferruginous soils and suffers high mining pressure (Fernandes, 2016). Mining has a direct effect on local habitat degradation through the removal of native vegetation and soil, as well as indirect effects by promoting changes at the landscape level, such as the opening of roads and secondary accesses, urbanization, deforestation for charcoal production, and intentional introduction of exotic species in rehabilitation projects (Fernandes, 2016; Sonter et al., 2014).

The Espinhaço range has the highest rates of plant endemism in South America (Fernandes, 2016) and high levels of endemism and diversity of amphibians (Leite et al., 2008). Recent descriptions of new anuran (Leite et al., 2012) and bird (Freitas et al., 2012) species in the Espinhaço indicate that many species, not yet known to science, might already be threatened. The Iron Quadrangle situated in the southernmost Espinhaço is also one of the world's largest gold and iron deposits (Lobato et al., 2001), accounting for 70% of the current Brazilian iron production (IBRAM, 2012). This region is also of utmost conservation concern (Silva et al., 2008) within the biologically rich Espinhaço, and has the highest anuran species richness level across the mountain range (Leite et al., 2008). More than 300 years of mineral extraction in the Iron Quadrangle have led to environmental contamination (Matschulla et al., 2007), with known impacts upon many endemic plant species (Jacobi et al., 2011). However, the impact of mining on the distribution range of the fauna in the Iron Quadrangle, and throughout the whole Espinhaço range, is still unknown.

Mountain species often have small and disjunct distributions, which may increase their vulnerability to ecological disturbances and increase their extinction risk (Harris and Pimm, 2008; Sobral-Souza et al., 2015). Small geographic range size has been found to be the best single predictor of extinction risk (Harris and Pimm, 2008). Mining activities in areas of high endemism and diversity are known to pose a considerable threat to local species (Jacobi

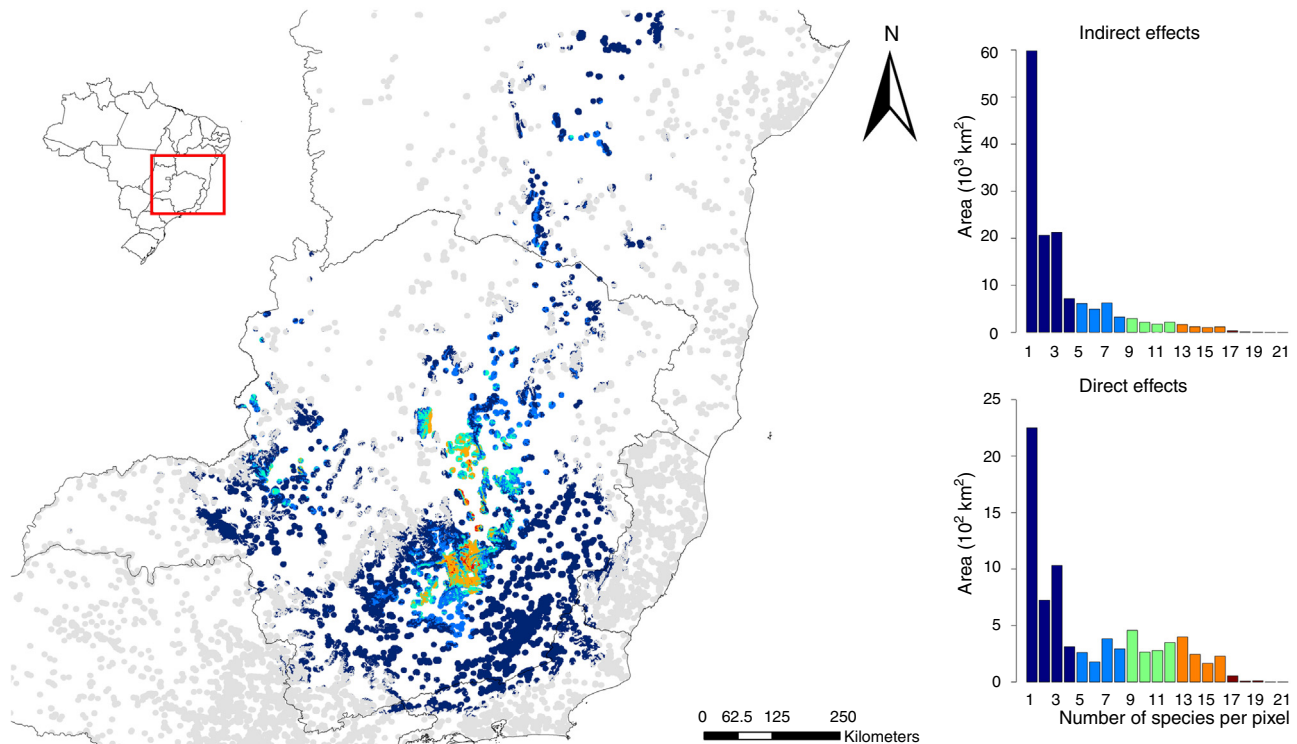
et al., 2011), and may have a disproportionately high impact in high altitude ecosystems. These drivers may have wide-ranging consequences as highland species might not have the chance to colonize similar habitats due to limited dispersion capability, large distances between suitable habitats, hostile intervening terrain, or even non-existence of similar habitats (see Fernandes, 2016).

In this study, we aimed to assess the direct and indirect impacts of mining activities on anuran and bird species endemic to the eastern Brazil mountaintops, based on ecological niche models (ENM). ENM have been used to model species potential distributions by associating occurrence records and environmental variables, enabling the identification of potential habitat areas even when sampling is incomplete (Pearson, 2007; Peterson et al., 2011). Potential distribution maps can be used to evaluate the spread of potential threats within a species geographical distribution (Pena et al., 2014). We also measured the local biodiversity rate to assess the impacts of mining activities on regions that are suitable for a high richness of bird and anuran species. We hypothesized that a high proportion of the potential habitat available for both anuran and bird species endemic to the eastern Brazil mountaintops will overlap with areas that are currently directly and especially indirectly affected by mining.

## Methods

### Study area and mining maps

We defined as our study area all Brazilian states that contain the occurrence points for the 41 anuran and 8 bird species endemic to the eastern Brazil mountaintops (S1 Table, S2 Table). Polygons of current mining activities for Bahia, Espírito Santo, Minas Gerais, Rio de Janeiro and São Paulo were acquired from the National Department of Mineral Resources (DNPM) website (<http://sigmine.dnpm.gov.br/webmap/>, accessed May 2016). These maps hold all records for mining extraction, licensed mines and



**Fig. 1.** The effects of mining activities on the estimated biodiversity rate for 41 anuran species, endemic to the eastern Brazil mountaintops. Polygons highlighted in gray represent mines officially approved and licensed for mining activity and their respective 5 km radius buffer, which did not overlap areas estimated as suitable for anuran species. Histograms highlight the area directly and indirectly affected by mining in each richness class identified by the biodiversity rate estimate.

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