Perspectives in Ecology and Conservation xxx (2017) xxx–xxx

Perspectives in ecology and conservation

Supported by Boticário Group Foundation for Nature Protection

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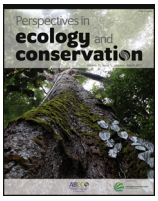

Research Letters

Rewilding the Atlantic Forest: Restoring the fauna and ecological interactions of a protected area

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ARTICLE INFO

Article history:
Received 6 June 2017
Accepted 13 September 2017
Available online xxx

Keywords:
Alouatta
Captive stock
Dasyprocta
Ecological interactions
Refaunation

ABSTRACT

The loss or reduction of animal populations and consequent extinction of ecological interactions in Neotropical forests demand urgent conservation initiatives to reverse these trends. One of the rainforests with the highest levels of mammal defaunation is the Brazilian Atlantic Forest. Local mammalian extinctions in the biome were evaluated to set out priorities. Researchers, reserve managers and *ex situ* animal keepers throughout the Atlantic Forest were connected through a reintroduction network. From 2010 to 2017, we reintroduced two important seed dispersers, the red-humped agouti and the brown howler monkey, in Tijuca National Park, Rio de Janeiro, with other species on their way. We monitored the reintroduced populations regarding demography, spatial patterns, diet and their effect on ecological interactions. They interacted with several plant species, including large-seeded ones. We found 25 dung beetles' species interacting with howlers' feces. As TNP lacked medium and large sized frugivores, the increased dispersal can have a disproportional effect on forest regeneration. Among the main constraints for refaunation programs we pointed out delays to obtain environmental licenses, scarcity of source populations and difficulties regarding quarantine, release and monitoring of the animals. Refaunation has shown promise as a low-cost, effective way to restore ecological processes in defaunated Neotropical forests.

Introduction

In the last years, there has been an increased awareness that we may be going through Earth's sixth extinction wave, comparable to the great mass extinctions of the geological past (Barnosky et al., 2011). This process started approximately 50,000 years ago, with the extinction of most of the world's megafauna following human dispersal around the globe (Araujo et al., 2017), and has become increasingly severe in recent times, including many local extinctions and drastic population declines, especially in the biodiversity-rich tropics (Johnson et al., 2017).

The loss or reduction of animal populations can lead to the loss of ecological interactions in ecosystems (Valiente-Banuet et al., 2015). Janzen (1974) was the first to point out that the extinction of ecological interactions can impair ecosystem functioning and services (Balvanera et al., 2006). In forests where seed dispersal has been disrupted, for example, piles of fruits and seeds rot on the ground, while the vegetation appears to be intact – the so-called "empty forest" syndrome (Redford, 1992). In an empty forest, the chances of a large seed to become a tree are slim (Kurten, 2013).

In the last decades, there has been an increased interest in rewilding, aiming to restore ecosystems by translocating ecologically or locally extinct species, or by replacing them. The use of proxies to replace species extinct for decades, centuries or even millennia has been increasingly debated (pleistocene rewilding,

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https://doi.org/10.1016/j.pecon.2017.09.004

Donlan et al., 2005), but such management practices are risky and have been heavily criticized (Caro, 2007; Oliveira-Santos and Fernandez, 2010). A simpler approach that has been widely used is the reintroduction of a single species' population in an area from where it was extirpated (IUCN/SSC, 2013). The best example in Brazil is the successful reintroduction of the golden lion tamarin (*Leontopithecus rosalia*) in part of its original range in northern Rio de Janeiro state (Kierulff et al., 2012). However, its effects on the restoration of ecological processes have seldom been evaluated (Seddon et al., 2014). Besides, isolated reintroduction initiatives may not be enough to restore ecosystem functioning shattered by widespread defaunation, as any species' biology imposes limitations on the interactions it can rewire.

To address this problem, Oliveira-Santos and Fernandez (2010) proposed the idea of refaunation – the restoration of native faunas. Implicit in their proposal was the so-called "Columbian baseline", the use of species present by the time of European colonization. This approach would be based in the sequential reintroduction of a set of recently extirpated animal species, allowing the restoration of ecological interactions with the extant fauna and flora. This is similar to "trophic rewilding" (Svenning et al., 2016), with the difference that the latter prioritizes the restoration of trophic interactions more than the fauna itself; we use the two terms as synonyms hereafter. To optimize the recovery of interactions and to allow subsequent recolonizations by other species, Galetti et al. (2017a) suggested a logical sequence of reintroductions that should be followed for the trophic rewilding of Neotropical forests.

The Atlantic Forest of Brazil, one of the World's richest biodiversity hotspots (Myers et al., 2000) but widely defaunated (Galetti et al., 2017b), is an obvious priority for refaunation. The ambitious idea of refaunating Atlantic Forest sites in Rio de Janeiro led to our first reintroduction in 2010, and to the creation of the REFAUNA Project in 2012. Our first goal was to map and evaluate local extinctions (extirpations) of mammals in the Atlantic Forest, and identify where refaunation initiatives would be most needed. We compared original and present distributions of all medium and large-sized mammals that occurred in the Atlantic Forest when the Portuguese colonization started in 1500, and estimated which proportion of its original distribution each species had lost. We then created a virtual reintroduction network, the REFAUNA Network (http://refauna.wixsite.com/site), to connect researchers, reserve managers and *ex situ* animal keepers throughout the Atlantic Forest biome. Besides, with the REFAUNA Project, we also aimed to carry out the reintroductions themselves, to restore ecological interactions. Our first refaunation target was Tijuca National Park (TNP), a widely defaunated Atlantic Forest reserve within Rio de Janeiro city. TNP suffered with deforestation due to agriculture, especially coffee and sugar cane plantations from the XVII to the XVIII century, together with hunting pressure. After a great effort of reforestation in XIX century (Dean, 1995), forest cover was restored, but the fauna remained impoverished. As Tijuca Forest is surrounded by an urbanized matrix, most species cannot naturally reoccupy the area. The history and isolation of TNP make it a suitable natural laboratory for rewilding. There we have reintroduced two species of mammals so far (the red-humped agouti *Dasyprocta leporina* and the howler monkey *Alouatta guariba*), with other reintroductions planned for the near future. Herein we present the procedures adopted and the success these reintroductions had in restoring ecological interactions. We conclude discussing the challenges we faced in our efforts in order to provide insights for future reintroduction and refaunation initiatives in Neotropical forests.

Atlantic Forest mammal losses

Only 11.7–16% of the Atlantic Forest original cover still remains (Ribeiro et al., 2009). Increasing population pressure along history led to intense forest fragmentation, which, together with poaching and diseases, have caused many local extinctions of medium and large bodied vertebrates (Canale et al., 2012; Galetti et al., 2017a), resulting in the loss of an average of 88% (±SE 9.6) of their original (1500 A.D.) distribution. Most Atlantic Forest remnants have lost most of their medium and large mammals.

Bringing together the efforts of the actors involved: the REFAUNA Network

One of the main caveats of any reintroduction is to find a source population. We believe captive animals are usually the best choice because using wild-caught animals brings risks to wild populations, as mammals often occur in low densities. Through the REFAUNA Network we listed 474 *ex situ* animal keepers among zoos (120) and other breeding facilities (354). There was a lack of information regarding many animal sources, however, and only 71 of the listed keepers informed their stock sizes to the Brazilian environmental institute (IBAMA). Besides animal sources, we also listed 2910 researchers and other conservation agents, and 318 protected areas suitable for reintroductions or refaunation (Fig. 1). Only 14 protected areas had all the seven species analyzed on REFAUNA Network (see Table 1; *A. guariba* and *Bradypus torquatus* were analyzed only for Rio de Janeiro state) and did not need reintroduction programs (Fig. 1).

An urgent target for the REFAUNA Network is Rio de Janeiro state, whose 26 fully protected areas (Biological Reserves and Parks) have lost most of their medium and large sized mammals (Table 1; Rocha et al., 2004). There are no resident populations of tapirs or jaguars in the whole state (Medici et al., 2012; Zeller, 2007). Although there is no single reserve large enough to maintain a viable jaguar population, the so-called Central Fluminense Mosaic covers nearly three hundred thousand hectares (Costa et al., 2010), and if its 29 protected areas are properly managed, it represents the only opportunity for reconstructing "complete" faunas, including apex predators.

Tijuca National Park as a laboratory for refaunation

Tijuca National Park (TNP) is a suitable laboratory for refaunation experiments. The area is a 3953 ha forest fully embedded in a metropolitan matrix – which means that fauna released there can be easily controlled and could not disperse to other forest fragments. A previous attempt for restoring TNP's fauna was carried out from the late sixties by Coimbra-Filho et al. (1973). Among other animals, individuals of six mammalian species – some of them still present in the park – were released, including 32 agoutis (*D. leporina*). The releases were widely separated in space and time, the released individuals were not monitored, and the population of agoutis disappeared soon afterwards. Our first steps have been the reintroductions of the red-humped agouti (*D. leporina*) and the brown howler monkey (*A. guariba*). Agoutis and howlers were presumably extinct due to habitat loss (TNP was deforested for sugar cane and coffee plantations and reforested in the 19th century) and over-exploitation. Although domestic and feral dogs can prey upon native fauna and extirpate populations (Lessa et al., 2016), we do not believe that this was the main cause of agouti extinction in TNP. The habitat has been restored, and there are no signs of intensive poaching in TNP today. Therefore, we believe the causes for their original extinction are now controlled.

Agoutis should be part of the early stages of trophic rewilding because they occupy a low position in the trophic chain and because of their pivotal role in restoring ecological interactions (Galetti et al., 2017b). The species disperses large seeds through long distances (>100 m; Jansen et al., 2012), and carry them toward locations with lower conspecific tree densities

Please cite this article in press as: Fernandez, F.A., et al. Rewilding the Atlantic Forest: Restoring the fauna and ecological interactions of a protected area. Perspect Ecol Conserv. (2017). https://doi.org/10.1016/j.pecon.2017.09.004