Recovering Connectivity Through Restoration Corridors in a Fragmented Landscape in the Magdalena River's Valley in Colombia

Nicolás Alejandro José Delgado Morales[1,2,3,4], Rafael S. Escucha[1,2,3,4], Andrés F. Montes[1,2,3,4] & Andrés Link [1,2,3,4]

[1] Universidad de los Andes, Bogotá 111711, Colombia.
[2] School of Sciences, Universidad de los Andes, Bogotá 111711, Colombia.
[3] Department of Biological Sciences, Universidad de los Andes, Bogotá 111711, Colombia.
[4] Laboratory of Ecology of Tropical Forests and Primatology, Universidad de los Andes, Bogotá 111711, Colombia.

Abstract

Forest fragmentation is one of the main drivers of the global decline of biodiversity. This ecological disruption has become pervasive during the last decades, and the emergence of isolated animal populations due to fragmentation, has risen. This study focuses on understanding the role of restoration corridors as a novel strategy promoting the resilience and viability of mammal and bird populations through increasing connectivity in the Middle Magdalena River Valley in Colombia. We installed 82 camera traps to monitor terrestrial and arboreal vertebrates within restoration corridors in a 4000-ha area located in Santander's Department, in Colombia, specifically at Cimitarra Municipality (6°26'40.54'' N 74°7'50.06'' W). Our main goal was to evaluate if mammal and bird species of the tropical humid forests in the Middle Magdalena River in Colombia were using restoration corridors and if restoration corridors were promoting reconnection between communities of terrestrial vertebrates. We completed a sampling effort of 8609 camera-trap days and four sampling sessions, each of 90 days of duration. Cameras were installed in four different scenarios associated with land cover: 1) forest fragments, 2) natural corridors, 3) stablished corridors and 4) pastures. Our findings suggest that there is more species richness in restoration corridors than in pastures, also we could find that the species composition in restoration corridors is beginning to look alike the species composition in forest fragments. Our results provide initial evidence on the role of restoration corridors as an efficient implementation aimed to protect and preserve biodiversity in fragmented landscapes.

Key words: restoration corridors, camera trapping, conservation strategies, connectivity, forest fragmentation

Introduction

One of the biggest threats to biodiversity and ecosystem dynamics at a global scale is forest fragmentation. Coupled with habitat degradation, overexploitation and other major anthropogenic disturbances, habitat fragmentation influences environmental changes that risk food security, safety, and shelter of thousands of species dependent on these types of ecosystems, including humans (Adronache *et al.* 2019). Also, fragmentation directly affects some species efficacy in dispersal success, changing the habitat structure and increasing mortality rate of certain species and causing a significant reduction in their genetic diversity. Fragmentation restricts species movement processes like migration or dispersal, increasing extinction risk for different forest-dwelling species (Cushman *et al.* 2013). The abovementioned are direct causes of habitat loss and have been generated by anthropic activities such as population establishments, road construction, agriculture, and deforestation mainly caused by cattle ranching (Mills, 2013).

Tropical ecosystems seem to be more affected by fragmentation and degradation than other types of ecosystems. These anthropogenic activities are directly deteriorating forest structure, causing an important decline in species biodiversity (Taubert et al. 2018). Although Tropical America still sustains larger proportion of land ecosystem coverage, compared to other continents, vertebrate's population's decline maintains drastically high levels. According to the Living Planet Index, vertebrate populations in the American Continent have had an average loss greater than 90% in the last 50 years (WWF, 2020). In South America, some of the most damaged ecosystems are found in the North-western part of the continent, there, dry and humid forests have been strongly affected by extensive livestock farming and large-scale agricultural monocultures (Correa Ayram et al. 2020). For example, in the Colombian Middle Magdalena Valley River monocultures and extensive cattle ranching have transformed more than 85% of the natural forests, and remaining forests and wetlands are highly fragmented (Correa Ayram et al. 2020). In fact, the Magdalena River's Valley is within one of the Global Biodiversity Hotspots: the Tumbes, Choco, Magdalena biodiversity hotspot (Myers et al. 2000). Thus, a great number of native species on this region are facing current threats to their existence and its populations, partly due to isolation in small forest fragments (De Luna & Link, 2018).

Currently, strategies to reduce deforestation rates in the Colombian context include protected areas, and environmental defenders and government institutions consider it as one non-exclusive alternative to reduce the biodiversity loss. A large amount of research regarding the role of protected areas on the conservation of biodiversity has been made and it has provided evidence that protected areas in Colombia - like indigenous reserves - could help reduce deforestation. However, the Colombian internal conflict must be considered as a variable that influences the success of protected areas, given that after the Peace Agreement signed in 2016, protected areas like Parques Nacionales Naturales and Reservas Nacionales Naturales revealed an increase of 177% in deforestation rates, partly driven by the pause in the armed conflict and the subsequent beginning of exploitation of natural resources in these areas causing forest fragmentation (Clerici et al. 2020). These data are relevant given that is necessary recognize that the implementation of conservation techniques such as forest restauration with biological corridors that ensure reconnection between forest fragments is imperative for maintain the well-being of species populations.

Given this scenario, Fundación Proyecto Primates (a local NGO) decided to implement restoration corridors – thin (20-30m) strips of restoration corridors between forest fragments - to mitigate these consequences and recover structural and functional connectivity between isolated subpopulations of plants and animals. Thus, restoration corridors are broadly defined as a structurally continuous conglomerate of vegetation that connects previously isolated forest fragments. Corridors may help provide resilience to wild populations through promoting movement of individuals across the corridors (Rosenberg, Noon & Meslow, 1997). It is estimated that restoration corridors allow movement in fragmented landscapes, achieving proper responses of animals to climate change to increase the probability of persistence as populations (Cushman et al. 2013). To stablish a partial solution to this problem, in this research we evaluate the efficacy of biological corridors created since 2016 at Hacienda Lucitania, in central Colombia, and their role in restoring wildlife connectivity between forest fragments. For this purpose, we installed camera traps across this fragmented landscape and the recently planted restoration corridors to monitor if terrestrial and arboreal vertebrates are indeed using, or not, restoration corridors to move across forest fragments.

General objective

The main goal of our study is to evaluate if biological corridors - implemented to promote ecosystem connectivity - are effectively reconnecting populations of terrestrial and arboreal vertebrates – including several threatened species - that were previously isolated in a fragmented landscape.

Specific objectives

- Provide evidence for species of the use of restoration corridors that have been stablished since 2016 by rainforest mammals and terrestrial birds in the Middle Magdalena River Valley
- Evaluate whether restoration corridors promote the reconnection of the terrestrial vertebrate community in the Middle Magdalena River Valley in Colombia.
- Analyse the difference between the use of restoration corridors and pastures to assess whether there is a preference for the use of corridors by species of mammals and terrestrial birds.

Methodology

Study area

This study took place at a 4000-ha area located in Santander's Department in Colombia (Fig. 1). Hacienda Lucitania's is a Civil Society Natural Reserve (RNSC) where conservation of species is promoted, therefore both hunting and logging are prohibited. This area is made up of fragments of tropical humid forest immersed in a matrix of pastures for cattle ranching. In past years, Fundación Proyecto Primates (FPP) has implemented 10 restoration corridors that connect approximately 1200-ha of forest fragments since 2016 (Fig. 1). Restoration corridors have between 1 to 6 years of being established (planted with native tree species), providing an exceptional scenario to evaluate the use of connectivity corridors by mammal and birds. In addition, the biodiversity assemblage in the study region is highly singular due to the presence of highly threatened species like the brown spider monkey (*Ateles hybrid*), the blue-billed curassow (*Crax alberti*), the jaguar (*Panthera onca*) and the South American lowland tapir (*Tapirus terrestris*).

Field methods

We used camera traps in order to monitor terrestrial vertebrates that are using restoration corridors. Overall, we used 82 camera traps deployed at four different types of land cover: at forest fragments we installed 32 cameras, at natural corridors we installed 14 cameras, at natural pre-existing corridors we used 23 cameras, and, at open pastures, we employed 13 cameras. All of them were used during a period of 90 days throughout four sampling session, from October 2021 to October 2022. Each location was chosen in relation to the expected biodiversity in each area (corridor, forest fragment, natural corridor, and pastures) taking pastures as a negative control – terrestrial animals could move from fragment to fragment- and forest fragments as positive controls – areas where most terrestrial animals persist. Camera traps were installed in each corridor at three specific points: beginning, middle and end of the corridor (Fig 1.) All cameras were installed at a minimum distance of 100m to reduce the dependency of data records, although we note they are not strictly independent from each other.

Analytical methods

For data analysis and animal identification we used Wild ID Software in which we reviewed an approximated total of 220.000 photos. Afterwards, we used R (R Core Team, 2022) and R Studio (RStudio Team, 2022) to estimate alpha diversity in terms of species richness in each of the four different types of land cover taken as categorical variables. This analysis helps us to determine how alpha diversity is changing, or not, across the four different categories of land cover sampled in this study. We used a generalized linear model (GLM) to evaluate how much species richness changed in each land cover with respect to the forest fragments. Then, we perform a non-metric multidimensional scaling analysis to determine how dissimilar were the vertebrate "assemblages" across land cover categories, which gives us an idea of how heterogeneous or homogeneous one category could be with respect to another. Altogether, we carry out an Analysis of Similarity (ANOSIM) to determine the escalated difference compared to the average of all groups. Analysis was conducted using different packages in R, among them: dplyr package (Wickham et al. 2022), tydiverse package (Wickham et al. 2019), camtrapR package (Niedballa et al. 2016), spacetime package (Pebesma, 2012) and vegan package (Oksanen et al. 2022).

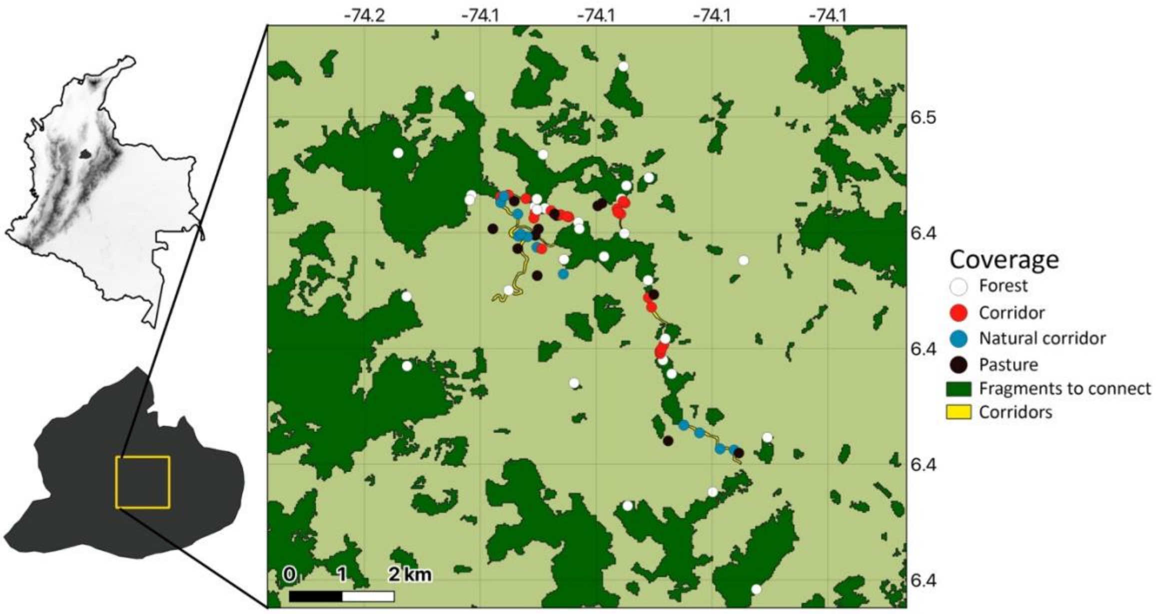

Figure 1. Camera trap locations along four types of land cover in a fragmented landscape at Cimitarra, in the middle Magdalena River basin.

Results

Our results support that species richness at forest fragments is higher than that in pastures and corridors. Moreover, natural corridors have a similar richness to the one that is found in the forest, this is probably due to similarities in composition. Also, the recently established corridors have a richness with intermediate values between natural corridors richness and pastures richness (Fig. 2) Those analysis had the following statistics and p-values: Forest –

Corridor (estimate = -0.57 & p-value < 0.001) / Forest – Natural Corridor (estimate = - 0.20 & p-value = 0.07) / Forest – Pasture (estimate = - 0.91& p-value < 0.001).

Using the GLM, we found that species richness in forests is drastically different in comparison to species richness in pastures, which is partly explained by differences in diversity between these land coverage categories. Those analysis had a significant p-value (< 0.001) (Fig. 2). In addition, we evaluate the four land covers, sampled thorough a non-metric multidimensional scaling analysis finding that in terms of composition, the difference between pastures and forest is highly significant (Fig. 3). Moreover, the natural corridors and the stablished ones keep a distribution that has been moving from the pasture's composition and has come closer to the forest's composition which is expected considering age and land cover in these environments (Fig. 2). We were also able to identify that data is more heterogeneous in the forest than in pastures and corridors. Our p-value of 0.001 shows that there is a significant difference in how categories are grouped into the space. Finally, our analysis of similarity (ANOSIM) showed a R = 0.143 and a p-value = 0.001 (Fig. 3).

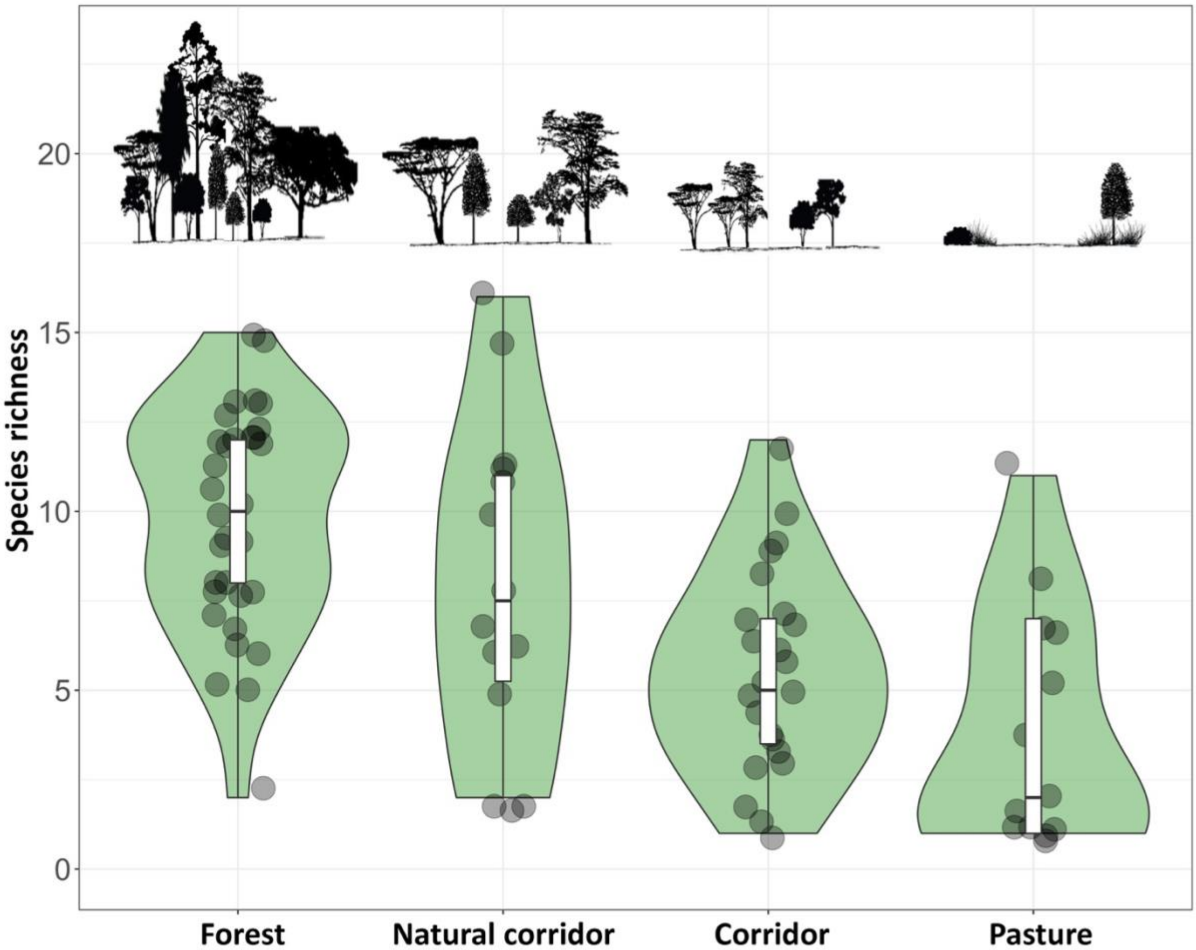

Figure 2. Species richness in 4 different types of land cover. Forest – Corridor **(estimate = -0.57 & p-value < 0.001)** / Forest – Natural Corridor **(estimate = - 0.20 & p-value = 0.07)** / Forest – Pasture **(estimate = - 0.91& p-value < 0.001)**

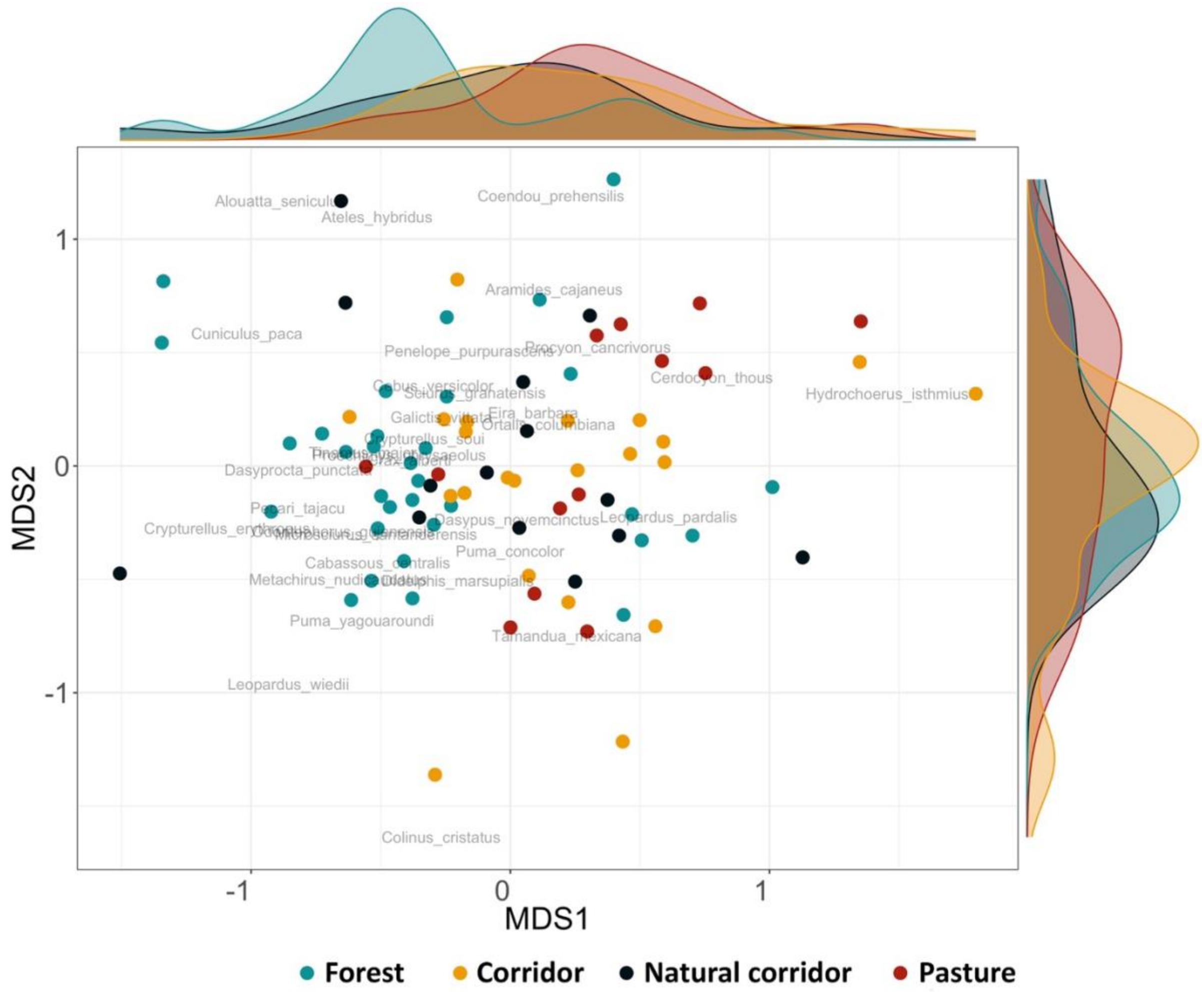

Figure 3. Non-metric multidimensional scaling analysis build from land cover types. ANOSIM: R = 0.143, p-value = 0.001

Discussion

Based on the results of our study, we have obtained initial evidence suggesting that restoration corridors have had a positive impact in reconnecting vertebrate populations the Middle Magdalena Valley, because they have a more heterogeneous area compared with pastures based on different types of soil and variation in microclimate. Forest fragments with more heterogeneity tend to be less susceptible to local extinctions than those who are more homogeneous (Mullu, 2016). However, the biological heterogeneity of pastures is mainly driven by the presence of generalist animals such as foxes and some felids. These animals tend to frequently use forest edges, since some other animals prefer to breed in these territories despite a considerable increase in predation's rate (Mullu, 2016). Hence, species more generalists tend to use pastures in greater extent (Pliscoff et al. 2020), while forest dependent species tend to use corridors more. Furthermore, we consider that pastures species richness is given by generalist animals such as the fox and some felids that tend to use those pastures. Also, it is known that some animals prefer to use forest edges for reproduction exposing themselves to predators (Mullu, 2016).

Additionally, based on the multidimensional scaling analysis graphic (Fig. 3) we could observe that species community in the corridors is composed of both forest species and pastures species, based on this, we could also mention that species richness in the corridors is a halfway point between pastures and forest's species richness, which show us that corridors are used more often by numerous species. Those intermediate values of richness suggest the same, that more species are using restoration corridors.

Finally, after analysing the obtained results, the increase in restoration corridors is a vital advantage in a long-term plan for the existence of species in this fragmented landscape since the vegetal area is increased allowing species to coexist between fragments. This is directly related with species richness because the greatest richness was found in forest fragments and the lowest, in pastures and corridors. Also, it is clear to say that many studies related to restoration corridors have been made and connectivity cannot always be an evident result. Many of these studies have found that restoration corridors indeed support conservation of species, nevertheless, for them to have a real effect the design in those studies represents an important role (Beirer & Noss, 1998). Furthermore, there has not been a preliminarily study that shows a negative effect of restoration corridors, this supports our idea of continuing with this strategy in order to reassure connectivity between fragments in the Middle Magdalena River Valley in Colombia (Beier & Noss, 1998)

Conclusion

In conclusion, the purpose of this research was based on evaluate if conservation strategies such as restoration corridors could contribute to solve connectivity and fragmentation problems in the Middle Magdalena Valley in Colombia. According to the obtained results, animals are using the stablished corridors to move between forest fragments, also we can state that species richness in the corridors is rising since environment and composition of the corridors are more similar to the forest and less to the pastures. Finally, we must set a precedent related to promote this conservation strategy in such a way that it groups different cattle ranching production systems; implementing restoration corridors to restore productivity in these habitats and protect biodiversity should be promoted. Moreover, this strategy must be accompanied from other efforts such as prohibition of hunting and avoid habitat degradation to have a relevant impact in the landscape and in the species populations.

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