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The effects of reforestation on mammal diversity and abundance in Monteverde, Costa Rica

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ABSTRACT

Reforestation is an important mechanism in helping previously deforested landscapes recover. However, reforested areas tend to have less diversity in vegetation, due to the fact that humans are not able to replicate the same diversity or pattern of regeneration that would occur naturally. I investigated whether or not these changes in forest types and vegetation affect the diversity and abundance of mammals that inhabit these areas. I used both camera traps and Sherman traps to survey mammals from areas with reforestation and with natural regeneration. I observed a total of 72 mammals from five species in the camera traps. I found that while there were no significant differences in the number of species present, there was a significantly larger number of individual mammal appearances on camera traps in locations with natural regeneration. I captured a total of 28 individual rodents over five species in the Sherman traps. Though I found more individual rodents in areas with reforestation, there was not a significant difference between areas with reforestation and natural regeneration. These results indicate that three of the five larger mammal species observed in the cameras (Nasua narica, Dasyprocta punctata, and Puma concolor) were significantly more abundant in areas with natural regeneration than reforestation. Though more research is needed to determine the specific reasons these species are less abundant in reforested areas, I speculate that it is due to dietary changes.
áreas regeneradas que en las reforestadas. Aunque hace falta investigar más para determinar razones específicas de menor abundancia en áreas reforestadas, que en este estudio especulo se debe a requerimientos de las dietas.

Human development has a large impact on natural biodiversity. This is often seen in the forms of habitat destruction or modification as humans develop areas for their own use. Central America, specifically Costa Rica, has been hit particularly hard by deforestation in the past. In the late 1980’s, deforestation reached a rate of 3.2% per year, which was the fifth highest rate in the world (Sánchez-Azofeif et al. 2001). Though trends in deforestation have been reversed in the past thirty years, the prior deforestation left many forest fragments and forest edges (Sánchez-Azofeif et al., 2001). These areas are unable to support large amounts of biodiversity and tend to lack organisms that require large amounts of space (Galletti et al., 2009). As Costa Rica is highly diverse, being home to nearly four percent of the world’s species, reforestation efforts have been largely important in maintaining the country’s immense diversity (Sánchez-Azofeif et al., 2001).

Though reforestation has helped to recover much of Costa Rica’s forests, it significantly changes the vegetation that would grow if the forests were able to regenerate naturally. Humans are not able to plant and allow for the spread of seeds the same way that would occur naturally. In reforested areas, there tends to be less biodiversity and a different species composition than in naturally regenerating forests (Oosterhoorn et al., 2000). For the purposes of this study, reforestation is defined as areas in which humans have planted some vegetation, and natural regeneration is defined as areas that have been allowed to recover without human planting.

Monteverde, Costa Rica, is a largely unique place in the sheer amount of biodiversity it hosts over such a small area (Martin et al., 2016). This is largely due to its status as a cloud forest, a tropical forest at a high elevation, which draws many unique species. Intact forests are extremely important in supporting the diversity it hosts, as forest fragments and edges decrease diversity and are not able to support large mammals. Because of this, there have been some reforestation efforts in previously deforested areas (Lamb et al., 2005). While reforestation is necessary to help preserve this diversity, some changes in the methodologies of reforestation may be needed in order to foster the same amount of diversity that would occur in a naturally regenerating forest (Mugwedi et al., 2017). A study done in the Andes in Colombia found that areas with reforestation had a lower abundance of medium sized mammals than natural forests, which indicates that mammals may be negatively affected by the differences in plant diversity in reforested areas (Sánchez et al., 2008). This study seeks to examine how forest edges reforested by humans change the diversity and abundance of mammals. Based on the differences in vegetation and plant diversity, I expect lower mammal diversity and abundance in reforested areas than in areas regenerating naturally.

MATERIALS AND METHODS

Study Sites

I observed mammal presence along a total of four edges with recovering forest in the Curi Cancha Reserve, La Calandria Reserve, and adjacent to Frank Joyce’s property near Bajo del Tigre, which will be referred to as the Bajo del Tigre site for the purposes of this project. The edges in Curi Cancha and Bajo del Tigre have been recovering by means of natural regeneration,
while both edges in La Calandria were reforested in 2003 (Hamilton 2017). The edge in Bajo del Tigre was along a pasture that was cut down approximately 60 years ago but has been allowed to recover relatively recently (Joyce 2017). The edge in Curi Cancha was created approximately 50 years ago and has been regenerating since June 2009 (Ramirez 2017). The first edge in La Calandria, referred to as La Calandria 1, had primarily *Inga punctata* and *Ocotea spp.* planted. La Calandria 2, the second edge in La Calandria, was reforested using *Ocotea floribunda* and *Ocotea monteverdensis* (Hamilton 2017).

**Camera Traps**

I placed three Bushnell HD camera traps at equal intervals on trees along each recovering edge to monitor medium and large mammal presence. However, one of the traps in Curi Cancha was nonfunctional, so only two traps recorded data there. I chained and locked each trap to the tree to prevent theft. I set each camera with medium sensitivity approximately a half meter up the tree to take three pictures every time it detected motion. I checked the camera traps and changed their SD Cards every five to six days. I included each mammal presence more than a minute apart even if I saw the same mammal twice, as for smaller mammals like agoutis, I could not differentiate between individuals. I did not include domestic animals, such as *Canis familiaris* and *Felis catus*, in the results. I set all the camera traps to record data between 22 November 2017 and 2 December 2017.

**Sherman Traps**

I placed seventeen to eighteen Sherman traps at site, each spaced evenly between ten and fifteen feet apart in alcoves where I expected to find rodents. I baited each trap with vanilla, oats, and rice, and rebaited them the next morning if necessary. I placed them at each site for three consecutive days and checked them each morning for rodents. If I found rodents, I recorded their weight, tail length, foot length, species, and gender. I then returned them to the location where I captured them. I used these measurements to help figure out which rodents were recaptured. I trimmed a section of their fur in order to recognize whether or not I recaptured rodents, as I did not include these in the results. I counted a rodent presence if I found a rodent in a trap or if I found part of the tail, but not the rodent, in the trap. I photographed rodents and identified them using *The Mammals of Costa Rica* (Wainwright 2007). When I captured rodents, I washed their traps before resetting them. I set all the Sherman traps between 20 November 2017 and 30 November 2017.

**Data Analysis**

I analyzed camera trap data both in terms of the number of species and the number of individual appearances. I analyzed Sherman trap data using the number of species and the number of rodents captured, excluding recaptures. I compared data between naturally regenerating and reforested areas, and between sites. I analyzed the results using Chi Squared tests. I used this because this tests for differences between distributions, so it was effective in testing the differences between the numbers of species and abundances.
RESULTS

Camera Traps

I set 11 traps for a total of 2134 hour between 22 November 2017 and 2 December 2017. The cameras in Curi Cancha Reserve recorded a total of 435 hours, while the cameras in Bajo del Tigre recorded a total of 602 hours, for a total of 1,037 hours in the sites with natural regeneration. The first site in La Calandria recorded a total of 440 hours, while the second recorded 656 hours, for a total of 1,096 hours in the sites with reforestation. They recorded a total of five species of mammals: *Nasua narica* (White-nosed coati), *Puma concolor* (Cougar), *Dasyprocta punctata* (Central American agouti), *Dasypus novemcinctus* (Nine-banded armadillo), and *Didelphis marsupialis* (Common opossum). There was a total of 72 individual mammal appearances (Fig. 1).

At the sites with natural regeneration, I observed five species of mammals, with a total of 64 individual appearances (Fig. 1). The site in Curi Cancha had five species with 53 appearances, and Bajo del Tigre had three species with 11 appearances. The sites with reforestation, both in La Calandria Reserve, recorded a total of eight individual appearances across three species. The first site in La Calandria had six appearances across three species, and the second site had two appearances from two species (Fig. 2). The difference in number of species between reforested and naturally regenerated sites was not significant, though the difference in the number of individual appearances was significant (Fig. 1, Chi Squared test, p<0.01, df=1). Curi Cancha had significantly more individual appearances than any other site (Fig. 2, Chi Squared test, p<0.01, df=3), though when Curi Cancha was excluded from the results, Bajo del Tigre still had significantly more individual appearances than the reforested sites (Fig. 2, Chi Squared test, p<0.05, d=2), which showed there were more individual appearances in each naturally regenerating site than in the reforested sites.
Overall, areas with natural regeneration had more species present, though this was not statistically significant. However, there were significantly more individual appearances of *N. narica*, *P. concolor*, and *D. punctata* in naturally regenerating than in reforested areas (Figs. 3 & 4, Chi Squared test, \( p<0.05 \), df=1).
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Figure 4: Species Distributions Across the Different Sites

**Sherman Traps**

I placed a total of 212 Sherman traps over ten days, which caught a total of 28 rodents. I identified a total of five rodent species: *Heteromys nubicolens*, *Tylomys watsoni*, *Oligoryzomys fulvescens*, *Scotinomys teguina*, and *Sigmodon hispidus*. Three species were seen in both areas with natural regeneration and reforestation, which was not a significant difference. Naturally recovering areas had ten individuals captured, while reforested areas had 18 (Fig. 5), which was also not a significant difference.

Figure 5: Rodent Species and Individuals in Areas with Natural Regeneration and Reforestation
La Calandria 2 had the most captures, with 12 individuals captured over three days. However, it also had the least diversity, with only one species (*H. nubicolens*) present. La Calandria 1 had the most diversity, with three species, and six total captures. Only two rodents were caught in Curi Cancha, though each was a different species. Bajo del Tigre had eight rodents captured between two species (Fig. 6). Though I captured five species in total, *H. nubicolens* was the only species to be caught more than once, and was most abundant in areas with reforestation, especially La Calandria 2 (Fig. 7). The difference in number of species caught and individuals caught between sites was not significant. However, when I examined only *H. nubicolens*, there was a significant difference in the number captured over site (Fig. 7, Chi Squared test, p<0.05, df=3), though not in naturally regenerating versus reforested areas.

![Figure 6: Rodent Distribution Across the Different Sites](image)
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DISCUSSION

Medium and Large Mammals

Significantly more large mammals were photographed in areas with natural regeneration than in areas with reforestation, yet there was a no difference in the number of species present between these. I observed more species in the areas with natural generation, but as I only observed five species in total, it is difficult to generalize about the relative species diversities. However, the significant difference in the number of individual appearances based on the type of site indicates that sites with natural regeneration have higher abundances of mammals than reforested sites. This is likely due to the natural regeneration sites’ abilities to support a more complex diet and habitat with its more diverse plants (Oosterhoorn et al., 2000).

When I compared the individual appearance data between Curi Cancha and Bajo del Tigre, there was a significant difference between the two sites, with Curi Cancha having significantly more individual appearances. This was likely since it was the only site that was not a fragment and was connected to a larger, continuous forest. Because of this, I excluded it from the data and compared Bajo del Tigre to the sites with reforestation, which still showed a significant difference in abundance. Though Curi Cancha’s mammal abundance was likely increased by its connection to the larger forest, the fact that Bajo del Tigre still had a significantly larger mammal abundance than the La Calandria sites indicates that this increase was at least partly due to natural regeneration.

When individual appearances were broken down into species, *N. narica*, *P. concolor*, and *D. punctata* were shown to be significantly more abundant in areas of natural regeneration, while
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there were no significant differences in the distributions of *D. novemcinctus* and *D. marsupialis* between site. The reason for the lack of significant differences was likely because very few *D. novemcinctus* and *D. marsupialis* were seen at any of the sites, so it was hard to come to conclusions about their relative abundances in such a short time period. The increase in *N. narica* contradicted the study done by Sánchez in 2008, which found coatis to be the only species that had a higher abundance in areas of reforestation. Coatis (*N. narica*) typically survive well in many locations, in part since they can coexist with humans. All the sites were in locations in which coatis would not benefit from humans, as there was no one consistently giving them food scraps in these sites, which may account for the differences with the study done by Sánchez in 2008. They may have been less present in La Calandria since mostly *Inga spp.* and *Ocotea spp.* were planted there, whereas there was more plant diversity in the naturally regenerating sites. Coatis typically feed on arthropods and fruits and frequently feed on figs from *Ficus spp.* (Wainwright 2007). From personal observations, neither of the sites in La Calandria had large numbers of *Ficus spp.*, likely since none were planted here (Hamilton 2017), while the site in Curi Cancha had more of them. Additionally, areas with more diversity in vegetation support significantly more diversity in insects (He et al., 2009), which may be the reason for the higher abundance of coatis, as this would give them more types of insects to prey upon.

The increase in the diversity of *D. punctata* is also likely due to dietary factors. Central American agoutis (*D. punctata*) feed on many types of fruits but prefer the fruits of certain types of Arecales (Wainwright 2007). However, in La Calandria, there was a significantly higher abundance of Fabaceae and Lauraceae, as these were used in the reforestation that occurred here (Hamilton 2017). From personal observations, there were more Arecales and other plant families in the areas with natural regeneration, which may account for why agoutis were less abundant in reforested areas. The increase in *P. concolor* abundance is likely due to the increased abundance in prey. Curi Cancha, the only site with *P. concolor*, had significantly more individual appearances of medium sized mammals, which are common prey items for *P. concolor*. Some of these prey items include agoutis, opossums, and armadillos (Wainwright 2007), all of which were observed to be more abundant in Curi Cancha.

Throughout the project, there were several issues with the cameras. Several of them did not function or had a corrupt SD card, so they may not have taken pictures for several days of the experiment. However, this was distributed fairly equally across the sites, so there was still a similar number of hours of pictures taken between naturally regenerating sites and sites with reforestation. Another issue with the camera traps was that some shifted in position, so even though they were recording pictures, they were aimed above the height that many medium sized species would have passed by.

**Small Mammals**

There was no difference in number of rodent species between naturally regenerated areas and reforested areas. Other than *H. nubicolens*, only one rodent of each species was found, so it is not possible to make assumptions about their distributions and abundance with this little data. There were more individuals caught in reforested sites than there were in sites with natural regeneration, though this was not significant. There was a high abundance of potential rodent food sources in both the reforested and naturally regenerated sites, which is likely the reason for the lack of diversity and abundance between reforested and naturally regenerated sites.
There were no significant differences in the distributions of *H. nubicolens* between naturally regenerated areas and reforested areas. However, there were significant differences in the distribution of *H. nubicolens* between each site. These differences may be due to the different types of vegetation that grow at each site. La Calandria 2, the site with the most *H. nubicolens*, had *Inga punctata* and *Ocotea spp.* planted. *H. nubicolens* tend to consume lots of fruit (Wainwright 2007), so they may have been attracted to this site due to the fact that the two most commonly planted families (Fabaceae and Lauraceae) produce high quantities of potential food. Additionally, no other species of rodents were found at this site, so they may have had such a high abundance due to the lack of interspecific competition. La Calandria 1, which had fewer *H. nubicolens*, grew primarily *Ocotea floribunda* and *Ocotea monteverdensis*. The smaller numbers of *H. nubicolens* at this site may have been due to the differences in vegetation when compared with La Calandria 2 or based on the fact that other species of rodents were found here, so they may encounter competition.

This study showed a significant increase in the abundance of mammals in sites that are naturally regenerated as opposed to reforested. A study done in the Andes examining diversity of medium sized mammals in reforested areas showed a similar trend (Sánchez et al., 2008). However, few studies have been done examining the effects of reforestation on mammal diversity and abundance, so more studies are needed to examine this across different types of climates and life zones. Studies are needed to examine the potential reasons for the decreases in abundance of medium and large mammals in reforested areas, so that this can be attributed to something specific, like diet. They could also examine how specific plant species affect diversity and abundance of mammals. This would allow those involved in reforestation efforts to learn more about how to reforest in a way favorable for mammals that inhabit the area.

Additionally, studies need to be done examining the other factors that may have affected these results. There were many humans and domestic animals (*C. familiaris* and *F. catus*) seen in the cameras along my sites, so studies examining the role these play in mammal diversity would be very useful.

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LITERATURE CITED

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