

Fragmentation Reduces Dietary Diversity, yet Expands Dietary Options of Madagascar Lemurs

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Tropical forests are a reservoir of unique medicines, rare species, and valuable resources. They are the densest habitats on earth and contain many resources for products that are in high demand. To meet this demand, these resources are harvested from forests causing major environmental destruction, such as fragmentation. Fragmentation refers to cutting down a forest in a way that leaves only isolated sections of the forest behind. This process not only reduces the total amount of forest available, but also creates an imbalance in the ratio of edge species to interior species. As a result, many animals that thrive in the interior of tropical forests are unable to survive. By studying how fragmentation affects a certain type of organism, the consequences of tropical deforestation can be determined. In this paper, I review the effect of fragmentation on the habitat and diet of lemurs.

The first part of assessing how lemurs adapt to fragmentation is to examine their original habitat. One example of a lemur species that has suffered from fragmentation is *Prolemur simus*, more commonly known as the greater bamboo lemur. This species of lemur is predominantly found within remnants of tropical forests in eastern Madagascar (Olson et al., 2013). Lemurs are much more common in areas of high bamboo density and low anthropogenic disturbance, or disturbance caused by humans (Olson et al., 2013). This indicates the preference of *P. simus* to live in rather undisturbed areas with large sources of their primary food options. King et al., (2013) hypothesized that fragmented forests likely contain smaller populations of *P. simus* because fragmentation reduces the total amount of bamboo present within the forest. This hypothesis also agrees with the findings that fragmented forest are sites of high anthropogenic disturbance, where lemurs are less likely to live (Olson et al., 2013). Furthermore, moderate amounts of naturally fallen trees and minimal human disturbance were reported in sites that lemurs were found in a study done by Olson et al., (2013). Considering these preferences, the preferred habitat of lemurs is likely undisturbed forests with large amounts of bamboo.

A similar species, *Propithecus diadema*, is also endemic to rainforests of eastern Madagascar. Populations of these lemurs can be found in both continuous and fragmented forests throughout the region (Irwin, 2008). These forests are abundant in mistletoe, another source of food for lemurs, along with several types of bamboo in smaller quantities (Irwin, 2008). Fragmented forests are less diverse, containing a higher percentage of mistletoe (Irwin, 2008). However, when their diet was less restricted in continuous forests, *P. diadema* consumed a larger amount of alternative species (Irwin, 2008). Overall, the variety of food sources available in different areas of tropical forests tend to strongly correlate with the regions that lemurs inhabit.

The natural diet of lemurs provides a basis upon which diet changes as a result of fragmentation can be compared. King et al., (2013) showed that large-culmed bamboo can

constitute more than ninety percent of a lemur's diet. However, there are at least twenty-nine species of large-culmed bamboo proven to be food sources of *P. simus*, such as, *Cathariostachys madagascariensis*, *Valiha diffusa*, *Bambusa vulgaris* and the genus, *Arundinaria* (King et al., 2013). The diet of *P. diadema* is also high in *Bakerella clavata*, or mistletoe, because it is found in large amounts in the forests where they live (Irwin, 2008). Still, over 150 species of plants were identified as food sources for *P. diadema*, indicating a desire for diversity in their diet, when possible (Irwin, 2008). Irwin (2008) showed lemurs consume mistletoe over seven percent more in fragmented forests than they do in continuous forests. These results demonstrate how lemurs are forced to change their diet when they have limited options available.

By examining dietary changes in continuous forests versus fragmented forests, I was able to understand how lemurs adapt. Irwin (2008) confirmed that there is a difference in both available food sources and the diet of lemurs between these two types of forests. Two continuous forests and two neighboring fragmented forests in the Tsinjoarivo Forest of Madagascar were analyzed for one year. The results indicate that lemurs have a higher ratio of leaf to fruit consumption in fragmented forests than in continuous forests (Irwin, 2008). Lemurs feed on all parts of plants, depending on the season. During the dry season, bamboo shoots are the most common part consumed, whereas during the wet season, lemurs turn to other parts, such as leaves and branch shoots (King et al., 2013). Additional species consumed by lemurs varied greatly between forests, especially between the continuous and fragmented forests (King et al., 2013). Correspondingly, lemurs in fragmented forests consumed mistletoe more often and had a less diverse diet than lemurs in continuous forests (Irwin, 2008). Finally, alternative species are available in higher concentrations in continuous forests, when compared to forests that have suffered from fragmentation (Olson et al., 2013). With this lack of variety in fragmented forests, lemurs consume the primary food sources that are more available.

Another way of predicting how lemurs adapt to fragmentation is to study how similar species have already been forced to adapt. Howler monkeys and great-maned sloths have been studied to observe dietary changes due to forest destruction (Bonilla-Sanchez et al., 2012) (Cassano et al., 2011). Both animals are also arboreal and are found within tropical forests at about the same latitude. They are slightly larger than lemurs, yet feed primarily on shoots and leaves of the plants in which they inhabit, as lemurs do. Bonilla-Sanchez et al. (2012) focused on how howler monkeys in fragmented forests responded to eucalyptus plantations that were planted right next to these forests. The monkeys spent the majority of their time in eucalyptus plantations and increased their population size during the three-year study (Bonilla-Sanchez et al., 2012). The howler monkeys fed almost exclusively on the native vegetation within eucalyptus agroforests, yet spent very minimal time consuming eucalyptus plants themselves. Maned-sloths showed a similar trend when they were observed in cacao agroforests, or cabruças, in Brazil (Cassano et al., 2011). In this instance, sloths changed their diet habits in cabruças by consuming mostly shade-intolerant plants, whereas in fragmented forests, sloths regularly consumed shade-tolerant species. Sloths were found in a higher concentration in these agroforests than predicted and were able to adapt their diets according to the species present (Cassano et al., 2011). These results demonstrate the success

*This author wrote the paper as a part of BIOL133: Biology Inquiry: Tropical Forest Biology under the direction of Dr. Westley.

of similar organisms to adapt to new habitats and find new sources of food. Because lemurs feed on a similarly diverse diet, they may be equally as efficient in altering their diet, when new species are available in large amounts.

Fragmentation is a problem in tropical forests around the world and is destroying more and more forests every year. This loss not only affects human businesses and consumers that rely on resources of tropical forests, but it more critically affects the species living in these forests. Endemic species, like lemurs, are forced to change their diets along with their habitats, as a result of this extensive loss of trees and plants. Continuous forests have shown a higher range of diversity, whereas lemurs feeding in fragmented forests are restricted to a smaller variety of species. Because of these dietary restrictions, lemurs would seem to stray away from these forests in order to find greater diversity. Howler monkeys and maned-sloths have shown this behavior when new agroforests were grown next to fragmented forests. Both species were able to successfully adapt their diets and thrive in the new habitats.

This leads to two conclusions about the effect of fragmentation on lemurs. First, fragmentation severely limits the diversity of plant species consumed by lemurs and therefore, limits lemurs' diet to only species that have survived deforestation. Secondly, lemurs are expected to behave as similar species have already been reported to do, by wandering outside of their native habitats to find new sources of food. This behavior is beneficial for lemurs, but it may cause many problems for other species. Two possible effects include a disruption in the feeding behaviors of other endemic species and a reduction in the abundance of species not usually consumed by lemurs. This may decrease the food sources of other animals and they will be forced to adapt, themselves, if they are to survive. An ongoing chain reaction of behavioral and dietary changes has already begun. That is why adaptability is most likely the key to survival for lemurs in Madagascar, where fragmentation has become common. It offers hope for the restoration of lemur populations that have been reduced by fragmentation, but not without consequences to other species living in the same area.

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