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Ecosystem services provided by black howler monkeys in human-modified habitats

Tropical forests are irreplaceable safeguards for biodiversity. Deforestation and the conversion of tropical forests to cattle pasture and urban centers represent a major threat to this biodiversity (Díaz et al., 2019). Specifically for Mexico, government policies in the 1960s campaigned to deforest the southeast part of the country for industrial cattle production to take advantage of the demand for beef and meet the unsustainable requirements of rich societies (de Jong et al., 2000; Estrada et al., 2019). Unsurprisingly, this drastic change in land cover has been driving significant rates of local extinctions (Dirzo et al., 2014). This situation leads to a clear example of a domino effect, in which the loss of crucial native species fuels the deterioration of tropical ecosystems that depend on the natural services they provide (Dirzo et al., 2014). These effects exacerbate worsening climate change effects, leading to diminished quality of life for the animal and human populations alike. Unluckily, the consequences of these events are unequally distributed, and the repercussions are worse for those that live in the tropics (Díaz et al., 2019).

The tropics are home to nearly all of our closest biological relatives, the non-human primates, with 97% of them inhabiting a wide range of tropical ecosystems (Estrada et al., 2022). For the specific case of tropical rainforests, the loss and transformation of habitat lead to primate declines through disruptions to their movement, changes in resource availability, and negative impacts of human activities, like illegal hunting, pet trade, and roadkill (Estrada et al., 2019). The resulting modified landscapes often cannot support primate species, but in cases where flexible primates may still occupy such areas, research is needed to understand how they acquire food, adjust their behavior to habitat modifications, and contribute to ecosystem services. Healthy primate populations support the natural functioning of tropical communities by providing essential ecosystem services, such as dispersing the seeds of trees or facilitating pollination (Estrada et al., 2022). Primate populations also represent major aspects of local human culture, society, and economy, and their declines and extinction risk represent the wide range of fallout should they not receive conservation attention and help.

To set up a research project that aims to evaluate the effects of anthropogenic disturbance (e.g., forest fragmentation and habitat quality deterioration) on primate movement and the long-term conservation outlook of a tropical ecosystem, I traveled to Palenque Chiapas, Mexico to conduct a 10-week pilot study for my Ph.D. research, generously funded by the Center for Latin American Studies. The primate species I am focusing my research on is the Yucatan black howler monkey (*Alouatta pigra*), locally known as *mono saraguato*. The black howler is a relatively big, diurnal, and fully arboreal primate that lives in groups of 2 to 12 individuals, with one or two adult males, two to four adult females, and their offspring (Estrada et al., 2006). They are distributed in southeast Mexico, a portion of Guatemala, and Belize, and just like the overwhelming 68% of primate species globally, they are endangered (Estrada et al., 2022). Black howlers are known to have some flexibility regarding the areas that they can exploit, allowing them to *survive* in disturbed habitats (Klass et al., 2020) where most other large, frugivorous vertebrates, sensitive to habitat loss, have already been extirpated (Ceballos et al. 2017).

During the first week in Palenque, my research team and I visited 15 potential study sites to talk to the landowners and request their permission to conduct a study on their property. We obtained permission from eight landowners who gladly offered their land and support during our research. During this time, we thoroughly assessed the feasibility of conducting a 1-yearlong study at each of these sites. This was a necessary step since a site may seem promising at first glance, but we needed to evaluate aspects such as entering and exiting the fragment safely each day and safely spending a 12-hr day inside the fragment. We also conducted surveys to determine the presence or absence of black howler monkey groups by listening to the howler's morning chorus and following the sound. To further evaluate the study sites and select the final four forest fragments that will accompany the last site and control, represented by the conserved primary forest of Palenque National Park, we conducted vegetation surveys to assess a preliminary level of vegetation disturbance.

Once we selected the study sites, we began the collection of preliminary data on one group of black howler monkeys inhabiting each site. On each first day of the observation weeks, we arrived at the sites before sunrise in the hopes that our focal groups would wake up with a morning howling bout. This strategy helps to find groups faster and begin the data collection from the start of their day. On days that the groups decided not to howl, we began a survey by

identifying potential sleeping trees from afar and searching for the roosting monkeys through the forest canopy. For the following observation day, we would plan to search for the group near where we left the group the previous afternoon, which allowed us to find them faster. Each observation day (33 in total) we completed during this phase consisted of collecting behavioral data in two different ways. The first method focused on a single individual by following it closely during the whole day and registering their behavior every two minutes to get the most detail on their feeding habits. The second method focuses on all the group members, registering their behavior and location every 15 minutes. We also collected data on their collective travel behavior and the tree species that they fed on. Since the most intriguing part of this study was to actually observe the seeds they were dispersing, we collected the fecal samples from the focal individuals we had followed the previous day to extract the fruit seeds and identify the plant species they were dispersing. This last part would get especially difficult when the monkeys fed on different types of *Ficus* sp. trees. Those seeds are very small, and it would take a tremendous effort to find and count them all. Overall, in this pilot study, we successfully tested the data collection methods and field equipment and made important changes in the protocol that will permit the collection of data on individuals and feeding species in a more efficient way. I hope that my study can begin to illustrate the tremendous work still needed to respect and protect black howler monkeys and their habitat in an area that is fully dependent on them.

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