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Bats and the Vanishing Rain Forests of Mexico
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by Alejandro Estrada and Rosamond Coates-Estrada

Tropical rain forests are the most diverse and complex terrestrial ecosystems on this planet. Harboring as much as 70 percent of all known species of organisms, rain forests are a source not only of climatic stability but also of many products used today by humans, ranging from food to pharmaceuticals. Current FAO* estimates suggest that over 38 million acres of rain forest are cleared every year worldwide, resulting in the local and regional extinction of many species, likely including some never even discovered.

In the Neotropics, clearing rain forests has also meant destroying and fragmenting the natural habitats of many bat species. Bats are numerous in these rich ecosystems, where they account for about 50 percent of the mammalian species and are critical participants in regenerating the forest. The northernmost limits of the Amazon rain forest reach as far as the Los Tuxtlas region in southern Veracruz, Mexico, but here, as elsewhere throughout southern Mexico, land-management practices have converted 80 to 90 percent of the forest to pastures. Today, groups of various-sized fragments, each with different histories of isolation, are all that remain. The pasture lands now constitute the "sea" in which the remaining rain forests occur as isolated "islands" of vegetation.

To parcel out their cleared land, farmers and ranchers of Los Tuxtlas, as elsewhere in the wet Neotropics, use live posts of the mulato tree (*Bursera simaruba*) to create barbed-wire fences. Because the trees grow rapidly and produce moderately foliated crowns, single rows of these living fences provide corridors of vegetation across the pastures. Agricultural activities occur sporadically in this sea of pasture and include planting seasonal crops such as corn, jalapeño pepper, beans, and tobacco. Other crops consist of arboreal plants, such as coffee, cacao, allspice, citrus, and mixed crops, which may also include cacao and bananas. At some of these plantations, farmers have left a few tall rain forest trees to provide shade. Here the flora is particularly rich, with the trees harboring bromeliads, orchids, and many other climbing plants.

Until recently, we knew little about how bats were responding to this environmental change and to the fragmentation and isolation of their habitat. We also did not know which species survived destruction of Los Tuxtlas' rain forests, whether they were confined only to the forest patches, or might in some way be utilizing the agricultural lands. Thus, three years ago we initiated a study to determine how bats have adapted to the transformation of their original habitat.

We began in the rain forest islands, using mist nets to census the bat communities, banding the bats before releasing them, and using a standardized sampling procedure to compare data across sites and types of vegetation. We surveyed slightly over 100 forest islands, ranging in size from two to 5,000 acres and dispersed over an area covering about 300 square miles.
Our studies revealed much that will enable us to form a conservation strategy for the remaining forest and its bat communities. The surveys showed that, in spite of extensive destruction of the rain forest, there still exists a rich species pool of bats that have managed somehow to survive the devastation of their original habitat. We detected the presence of 35 species□80 percent of those historically reported in the area. Seven species strongly dominated

the bat community and accounted for 80 percent of all bats found the short-tailed leaf-nosed bat (*Carollia* brevicauda), the mustached bat (*Pteronotus parnellii*), the yellow-shouldered bat (*Sturnira lilium*), the great stripe-faced bat (*Vampyrodes major*), the Jamaican fruit bat (*Artibeus jamaicensis*), the dwarf fruit bat (*A. phaeotis*), and the lowland fruit bat, *A. toltecus*.

One of our most important discoveries was that small forest fragments were as rich in species as large fragments, but that they had in common only about 60 percent of all species detected. We also found that the distance that isolates the islands of forest was inversely associated with species richness in each patch of forest. Distance, therefore, plays a critical role in influencing the diversity of bat species in the remaining forest fragments. If the islands were closer to one another, the diversity would be even greater.

In trying to learn how bats were adapting to this fragmentation of their forest home, we turned to the agricultural lands. Were bats present in these human-made environments? And, if so, were they having any effect on the crops introduced by humans? First, our efforts failed to capture bats in the pasture sites studied, but this may have been the result of these sites' being totally devoid of vegetation except for the low grasses grazed by cattle. Such habitats may be inadequate to sustain bats because pastures lack sufficient cover, food resources, and roosting sites. However, we did observe bats flying across these pastures, but well above net level. We witnessed bat falcons (*Falco rufigularis*) and owls (*Tyto alba*) preying on bats at dusk as they flew out of the forest into the open fields, suggesting that exposure to predators may also be greater in these habitats.

In contrast to pastures, we were very surprised to discover a great number of forest bats in arboreal crops such as cacao, coffee, citrus, allspice, and the mixed-crop plantations that are scattered throughout the region. We recaptured banded bats as they moved from forest island to forest island and from forest to plantation and to live fences. Distances ranged from a quarter of a mile to five miles away from the forest patch where we originally banded them. The species that appeared to move around the most were often the same as those found in the agricultural areas.

Because of the disappearance of the forest and the abundance of cattle, we expected vampire bats (*Desmodus rotundus*) to be common in our nets, but they accounted for only 1 percent of captures in the forest fragments studied. Vampires were also netted in some of the agricultural habitats and live fences, but here too they amounted to less than 1 percent of bats captured. This could be due to the common practice of Los Tuxtlas ranchers to separate cows and calves in the afternoon, placing them in corrals. While the practice results in greater quantities of milk the next morning, it also allows vampires to find the cattle more easily in corrals, which are where most vampire attacks take place.

Although the agricultural habitats studied contributed to only 1 percent of the area of vegetation sampled (about 15,000 acres), 77 percent of the bat species recorded were present in these habitats, accounting for about 40 percent of our captures. One bat, the false vampire *(Vampyrum spectrum*), was caught only at mixed plantations. Species such as the great stripe-faced bat, the yellow-shouldered bat, the short-tailed leaf-nosed bat, and the dwarf fruit bat dominated the samples in agricultural habitats. Overall, forests and agricultural habitats had in common 74 percent of the species recorded.

Such results suggest that these bats use the remaining forest fragments and, interestingly, the more occasional human-made islands of vegetation, as stepping stones. Small forest patches and mixed-use plantations or live fences may therefore be critical to bats in a landscape where remaining forests are separated from each other by great spaces. In live fences we detected 34 percent of the species recorded in the forest. Such intermediate stopovers may diminish the time and energy bats have to expend when moving between forest islands.

The agricultural lands may also offer bats protection, temporary perch sites, food resources, and shelter during disturbances. It is possible that bat use of agricultural lands also reduces the negative effects of saturation in the forest fragments, thus lowering competition. Further, if the fragments are not too distant from one another, the presence of the human-created islands may help sustain biotic connection among the fragmented and isolated bat

populations. Such effects may, in part, temper the negative effects of area loss and isolation of the natural habitat, allowing bats to persist.

Both our observations and interviews with farmers indicate that crop damage by bats is nonexistent. Instead, bats forage on the insects and small vertebrates that are found in the arboreal plantations. We have observed bats using these cultivated trees as temporary roosts in which to rest and feed. Thus, the presence of bats in such habitats appears not to have a negative effect on the cultivated plants. In fact, it is possible that their presence is beneficial; bats foraging on insects could contribute significantly to the regulation of insects that damage the leaves, flowers, and fruits of cultivated trees.

Not all species, however, were equally elastic in their response to environmental change. Our data indicated that, of the vegetation types studied, only about 30 percent of the species seemed capable of using them all in addition to the forest. Other species were present in only one, two, or three types of human habitats. Further, 20 percent of the species were captured in forest habitats only, bats such as the white bat (*Diclidurus virgo*), Gray's spear-nosed bat (*Mimon bennettii*), and the lesser long-nosed bat (*Leptonycteris curasoae)***, among others. These species, however, have been observed at other tropical localities moving across open areas.

It is possible that specialized ecological requirements or behavioral constraints do not permit these species to take advantage of the opportunities present outside the forest fragment in which they reside. If this is true, it means that an important proportion of the bat species that have survived in the fragmented landscape of Los Tuxtlas is particularly sensitive to the continued deterioration of natural habitat and is at immediate risk of extinction. Obviously, the ideal conservation strategy for the bat fauna in Neotropical regions like Los Tuxtlas would be to preserve large extensions of rain forests. But since much of the forest has already been destroyed in many areas of southern Mexico, we need to find other options to preserve the remaining bat species without entering into further conflict with current land-management practices. Our studies point to the need to preserve both small and large forest fragments, because together they are the repositories of the remaining, though dispersed, bat diversity in Los Tuxtlas.

Based on our experience here, an appropriate strategy might be one that incorporates conserving archipelagos of forest islands. Each archipelago would consist of a collection of various-sized islands, not very far from one another, maximizing the number of species protected. Some of the space between forest fragments would be planted in arboreal crops. This would create intermediate stopovers for bats, facilitating the flow of species between forest patches, thus reducing the negative effects of physical and biotic isolation. The use of live fences would help further connect forest islands. In some cases, the spatial arrangement of the agricultural parcels could be manipulated to buffer the effects that occur at forest edges from wind exposure and desiccation, effects such as tree mortality, invasion of outside organisms, and further deterioration of the isolated fragments.

In addition, economic surveys we conducted in the region showed that some agricultural uses of the land may be more productive than cattle ranching. A marriage between the scenario just discussed and the possibility of using the cleared land in ways other than cattle ranching suggests a more diversified, and possibly healthier, local subsistence economy. Another conservation model might convert existing pasture into arboreal agricultural parcels rather than turning more forest into pasture.

Perhaps most important, any conservation strategy in the Neotropics needs to contemplate both the problems of the local inhabitants and the need to educate them about the importance of preserving their natural resources. It would be very difficult to educate locals about the need to preserve the bat fauna and the rain forest without also trying to find ways to make the land more productive for them and to help raise their standard of living. It is the goal of our studies to present, based on our findings, specific suggestions to the municipal, state, and federal agencies in Los Tuxtlas on how to improve land-management practices without further jeopardy to the remaining forests.

Conservation education is also critical for the people of Los Tuxtlas who, knowing little about their bat fauna, often indiscriminately kill beneficial bats in an attempt to control vampires. Vampire attacks on cattle are commonplace,

and local farmers react by searching for bat colonies in tree hollows and in the occasional caves, where they spray chemicals. In many cases, the bats are not vampires at all. In others, vampires share the roosts with beneficial species that are killed as well.

Finally, no model for rain forest conservation can ignore bats. Coupled with the conservation of the remaining forest fragments, turning pasture into arboreal crops would allow forest bats to persist and would retain the essential capacity of fruit- and nectar-feeding bats to regenerate the ecosystem via their pollination and seed-dispersal services. Such a model could also have important economic benefits for local human populations.
But the task of preserving the remaining bat fauna in Neotropical forests like those of Los Tuxtlas is not simple. The processes of forest destruction and isolation over several decades have likely reduced the size of bat populations for the majority of species and certainly have reduced the availability of suitable roosting sites and food resources. As a result, the remaining bat species live under precarious demographic, ecological, and genetic conditions that put them at risk of extinction. Without a conservation plan in place, we can expect further physical and biotic isolation and the loss of species.

For the moment, we could sum up our findings by saying that in the fragmented landscape of Los Tuxtlas, there is a rich bat community that needs protection and further investigation. The components of this community have responded differently to the fragmentation of their natural habitat. There are bat species that can successfully occupy a variety of habitats created by humans. At the other end are species that display intolerance and are at serious risk in this altered habitat. The majority, however, seem to fall between the two extremes.

We hope to continue investigating the bat fauna in the fragmented landscape of Los Tuxtlas. Many questions remain. How does bat use of arboreal plantations vary from season to season? Among bats that use such plantations, how intense is fidelity to continued use of forest fragments? What kinds of seeds are bats moving across the landscape, and what kinds of crop pests might they be helping to control? The answers to such questions can strengthen our knowledge and understanding of these fascinating animals and will help reinforce conservation programs.

(Bio)
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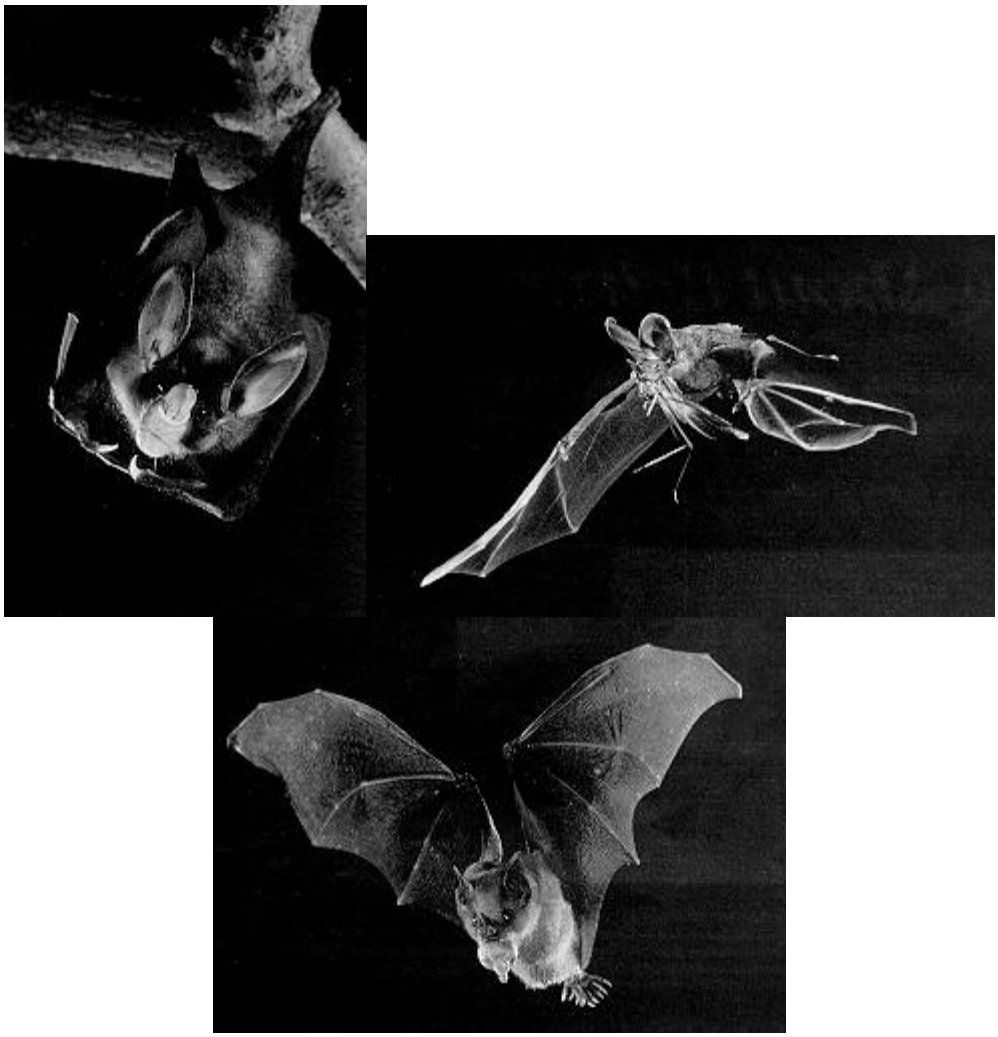
For further reading:
Estrada, A., R. Coates-Estrada, & D. Merritt, Jr. Bat species richness and abundance in tropical rain forest fragments and in agricultural habitats at Los Tuxtlas, Mexico. *Ecography*, No. 16, 1993

(Footnote 1)
* Food and Agricultural Organization of the United Nations, "Summary of the Final Report of the Forest Resources Association of 1990 for the Tropical World," March 1993.

(Footnote 2)
** Formerly *L. sanborni*.

Left: Despite widespread destruction of rain forests, a rich species pool of bats still exists in the fragmented landscape of Los Tuxtlas. The Jamaican fruit bat is one of seven species that dominate the bat community there.

A number of species moved between forest islands and agricultural habitat. Dwarf fruit bats (below) were among the species most often found in agricultural areas. Fruit bats like the lowland fruit bat (right) often drop seeds, such as this solanum berry, in their travels across the pastures between, leading to reforestation.



Some bats have adapted to the fragmentation of the landscape better than others. The false vampire (left) was found only in mixed plantations, but bats like this round-eared bat, Tonatia sylvicola, (top left) depend on primary rain forest for their survival and cannot exist without it. The yellow-shouldered bat, however, flies freely across cleared land, depositing vast quantities of seeds along the way. If the seeds were allowed to grow, the rain forest would soon reclaim the pastures.

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