# Habitat Fragmentation and Bats

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## Introduction

Habitat fragmentation is an anthropogenic global phenomenon that increases every year, and one that contributes to the increasing habitat destruction of a myriad of species and ecosystems. There are a couple of different causes of increasing forest fragmentation, although human encroachment lies at the foundation of any of them. One of them is the expansion of agriculture (Cleary, Waits, & Finegan, 2016; Frey-Ehrenbold, Bontadina, Arlettaz, & Obrist, 2013; Golnow & Lakes, 2014). A second cause would be the expansion in cattle ranching (Morton, DeFries, Shimabukuro, Anderson, Arai, del Bon Espirito-Santo, Freitas, & Morisette, 2006; Golnow & Lakes, 2014). Both of these causes ostensibly continue to expand with burgeoning human populations, but another issue behind both of these is mismanagement of food resources, a topic upon which an entire second paper could be written (Lotze, 2004; Giraldo, Betancur, & Arango, 2008).

Another increasing concern is human expansion through urbanization, which not only leads to habitat fragmentation but additionally introduces other foreign elements to which species must adapt. Examples of these include traffic, lights, noise, new edifices and structures to navigate, and change in predator structure (Fensome & Matthews, 2016). Fragmentation of natural landscapes has detrimental effects on numerous species and ecosystems. It can affect populations in different ways, and can have ramifications which change over time as diversity and populations change and adapt (or fail to adapt) to new circumstances. Some changes may be positive for certain species (the proliferation of urban species like pigeons and rats comes to mind), but the general trend has been negative changes in diversity and abundance throughout ecosystems.

This paper aims to look at the effects specifically on bat populations, particularly those in neotropical environments, where the highest levels of biodiversity occur. Bats make up around one-fourth of known mammal species in the world, and can often act as keystone species for given areas (Nature Conservancy, n.d.). Because of their the high diversity found particularly in neotropical regions, bats can display a number of different reactions to habitat fragmentation. Many of them suffer negative changes in genetic diversity and composition, in abundance, and in detrimental health and behavior changes. In one study, researchers demonstrated that bats might actually be unique reservoirs of emerging zoonotic diseases; there are a number of disease emergence incidences in bats that support this theory (Wang, Walker, & Poon, 2011). This is one of a number of ways that bats might be both particularly vulnerable as species and indicative of new and rising trends in certain ecosystems.

## Habitat Destruction

Habitat destruction through forest fragmentation affects bat species and populations in different ways. Some of the factors that can affect how bat populations react to habitat fragmentation relates to the behavior and physiology of particular bat species. For example, some species with greater flight range and mobility have been shown to have more resilience in fragmented habitats (Cosson, Pons, & Masson, 1999; Meyer, Struebig, & Willig, 2016; Russo & Ancillotto, 2015; Avile-Gomez, Moreno, Garcia-Morales, Zuria, Sanchez-Rojas, & Briones-Salas, 2015; McCulloch, Tello, Whitehead, Rolon-Mendoza, Maldonado-Rodriguez, & Stevens, 2013). The type of diet that bats consume can also affect their apparent resilience to habitat fragmentation. Part of this may tie into their mobility; for example, in a study in Costa Rica with the frugivorous bat species *Carollia castanea*, high genetic connectivity was found among populations of bats despite the presence of an agricultural landscape (Ripperger, Tshapka, Kalko, Rodriguez-Herrera, & Mayer, 2014). Genetic connectivity is important in reference to species' reproductive viability, resilience, and long-term survival; higher genetic connectivity is more indicative of positive overall trends for species (Braaker, Kormann, Bontadina, & Obrist, 2017).

However, this does not hold true for all frugivorous bat species; in a French Guiana study of one frugivorous bat species, *Rhinophylla pumilio*, their food resource was highly dispersed, and so in spite of the fact that they were highly mobile, they were still shown to be highly susceptible to negative effects of forest fragmentation. Landscape connectivity proved to be a much more positive indicator of population abundance with this species (Henry, Pons, & Cosson, 2007a). One study found that species which had already been documented previously as abundant in an area, such as *Artibeus jamaicensis* in Mexico, were less likely to be affected as a population over a 2-year period (Garcia-Garcia, Santos-Moreno, & Kraker-Castaneda, 2014). A study of eight phyllostomid populations in Mexico found great variation in bat species response to areas of deforestations, though all species in the study displayed some level of sensitivity (Avila-Gomez, Moreno, Garcia-Morales, Zuria, Sanchez-Rojas, & Briones-Salas, 2015).

How bats respond to fragmentation as individuals and as populations varies greatly, although most trends appear to be negative. There may be a decrease in abundance, a decrease in species diversity, or other less obvious changes, such as an increase in parasitism experienced by bats or decrease in gene flow or genetic diversity among species. Responses may vary; for example, in a single study of Amazonian bats, species demonstrated a wide variety in responses to fragmentation, with abundance correlating strongly with vegetative structure among species (Martins, Willig, Presley, & Marinho-filho, 2017). A few bat species have even been found to have favorable responses to fragmentation as the result of a positive change in roosting or foraging opportunities for them (Russo & Ancillotto, 2015). One study looked at how bat species in rubber and cacao plantation areas fared, and found that there was a high level of both abundance and diversity in species, although the lack of resources indicated that bats were probably using plantations as corridors (Heer, Helbig-Bonitz, Fernandes, Mello, & Kalko, 2015).

The level of fragmentation was also found to have significant impact on bat success: how much full and partial forest was available, the size, and the composition or vegetation, and density of cover available all affected bat usage and presence (Gorreson & Willig, 2004; Martins, Willig, Presley, & Marinho-filho, 2017; Mendes, Fonseca, Marques, Maia, & Pereira, 2017; Rocha, Lopez-Baucells, Ferneda, Groenenberg, Bobrowiec, Cabeza. . . & Meyer, 2017). Additionally, differences among the bat species themselves shaped response, such as original home range sizes, foraging strategies, and overall mobility (Cosson, Pons, & Masson, 1999; Meyer, Struebig, & Willig, 2016). Even the time of year and seasons can affect bat populations in fragmented areas, such as differences in the wet and dry seasons (Cisneros, Fagan, & Willig, 2015).

## Changes in Ecosystems

The presence or absence of bats in an ecosystem can result in other changes as well; bats can be viewed in many instances as indicator species for overall ecosystem health. For example, there are a number of plants that rely primarily on nectar-feeding bats for pollination, particularly in neotropical areas. Therefore plant reproductive success may suffer as a result of fewer bats being available to pollinate, as seen in a study on bat-pollinated plants in Mexico, where flowers in disturbed habitats were shown to be visited much less frequently by pollinator bats than those found in undisturbed habitats(Quesada, Stoner, Rosas-Guerrero, Palacios-Guevara, & Lobo, 2003). Researchers from this same study pointed out that fragmentation introduces a variety of new factors into the environment that could additionally negatively affect night-blooming flowers, such as the changes in lighting, cover, and connectivity from variation in coverage through forest fragmentation. Changes in plant/flower availability in turn can affect the bat populations, and therefore it may become difficult to distinguish which species is affecting which in some instances. Two of the three main primary pollinator species were found to be significantly reduced in visitation to trees in disturbed habitats in this study (Quesada, Stoner, Rosas-Guerrero, Palacios-Guevara, & Lobo, 2003). Another different study by many of the same researchers found in a slightly different area that the bat visitation of flowering plants varied greatly with the species of the bats and the flowers; possible explanations for these variations included differences in the bats' foraging behaviors, flowering patterns of the plants in the study, and self-incompatibility among plants, or the inability for a plant to self-pollinate (Quesada, Stoner, Lobo, Herrerias-Diego, Palacios-Guevara, Mungioa-Roses. . . & Rosas-Guerrero, 2004).

Researchers have also found another interesting micro effect on bats in fragmented areas: an increase in pest and parasite composition on bat hosts. One study in Panama found a significant increase in parasites on bats captured in forest fragments versus those in full tropical lowland forest (Cottontail, Wellinghausen, & Kalko, 2009). Another study in Costa Rica looked specifically at the composition of parasites and differences in female and male hosts, finding that in areas of increased bat species diversity, parasite abundance decreased on females and increased in males, presumably because of sex-specific roosting behavior differences; the effects were determined to be the results of anthropogenic impacts, however (Frank, Mendenhall, Judson, Daily, & Hadly, 2016). Cottontail et al. (2009) concluded that increased parasite prevalence was indicative of deteriorating health and increased disease prevalence due to habitat degradation. The effects of habitat destruction can therefore be observed throughout the spectrum of species.

## Urbanization and Bats

In addition to dealing with the effects of fragmentation, urbanization can introduce an entirely new set of factors for bat populations to deal with. Roadways lead to fatalities from vehicle collisions, can serve as barriers for mobility in foraging, and traffic noise and lighting could have other damaging effects on bats as well (Fensome & Mathews, 2016). Physical and chemical pollution from increased urbanization is another factor that can negatively affect bat populations (Russo & Ancillotto, 2015). Another study looked at bat use of human-made underpasses; bat species which were more used to flying in “cluttered airspace” tended to perform better in regards to fatalities and usage, than those more used to flying open air space (Abbott, Harrison, & Butler, 2012). Urban waterways have also been significantly impacted by the rapid rate of global urbanization; a study conducted in the United Kingdom found that human activity on urban waterways could negatively impact a variety of species in waterway zones up as far as 3 km from the source, as well as difficulties among certain species (pipistrelles in this study) in adapting at all (Lintott, Bunnefield, & Park, 2015). All of these studies demonstrate that a variety of often unintended or unanticipated consequences accompany urbanization of natural areas.

## Resilience in Bats

Some bat species have displayed more resilience in responding to habitat fragmentation. As mentioned, species that were previously found in abundance at some sites retained a strong presence despite fragmentation levels (Garcia-Garcia, Santos-Moreno, & Kraker-Castaneda, 2014). Another study in Paraguay and Argentina found that genetic changes did not occur among certain species despite fragmentation of habitat; they hypothesized that species which were more mobile and generalist could have greater resilience in resisting negative impacts of habitat fragmentation (McCullough, Tello, Whitehead, Rolon-Mendoza, Maldonado-Rodriguez, & Stevens, 2013). However, this is of concern because a great many species do not in fact have the same possibility of flexibility and mobility, whether due to constraints of physiology, morphology, behavior, or evolution into a smaller niche. One study of bats in Canada found the possibility of fragmentation having a positive effect on abundance in some species, which may have been related to roosting and foraging sites (Ethier & Fahrig, 2011). Thus, while some species may weather forest fragmentation, the fact remains that a decrease in bat biodiversity is a distinct possibility particularly in neotropical regions.

A few studies have even found not only neutral and sometimes unexpectedly more positive bat responses to forest fragmentation. In Panama, a study was conducted on small islands, and no negative responses were found among bat populations experiencing forest fragmentation (Estrada-Villegas, Meyer, & Kalko, 2010). Another study conducted in Brazil looked at both phyllostomid and open-space bat species; the latter were found to be equally distributed and found throughout the range, while phyllostomids varied greatly (Heer, Helbig-Bonits, Fernandes, Mello, & Kalko, 2015). This same study found high abundance and diversity in rubber-cacao plantations, despite the fact that there were few resources available for bats to exploit; it was thought that the other bat species were likely using the plantations as corridors.

**Possible Issues and Concerns with Research**

While most studies mentioned have indicated more negative impacts of bat species when it comes to agriculturalization, urbanization, and habitat fragmentation which results, not all researchers agree that using bats as an indicator species is accurate or ideal. One study looked specifically at the use of neotropical bats in this manner, and found enormous variations in both the sizes of experimental and control areas and bias in capture methods used, which may have led to species-biased findings, and whose various findings may have only represented a fraction of species diversity (20%) in study areas (Cunto & Bernard, 2012). Another study had correlating aspects, finding that phyllostomid species specifically were targeted by many of these studies, leaving out large swathes of other bat species (Estrada-Villegas, Meyer, & Kalko, 2010). Phyllostomidae is a large and diverse bat family, with around 160 species; however, it is by no means fully representative of all neotropical bat species (Burns, Hutzley, & Laubach, 2014).

Another study focused on two bat species in French Guiana, and concluded that traditional conceptions of “sensitivity” may have been incorrectly interpreted by other researchers (Henry, Cosson, & Pons, 2007a). However, even with these large flaws contended, researchers still concluded that studies of bats and habitat fragmentation possess value and can provide some insights into trends. Other researchers continue to contend that specific species are very likely in fact indicator species, as a result of presence in undisturbed forest versus absence or scarcity in fragmented areas (Stoner, Quesada, Rosas-Guerrero, & Lobo, 2002), and that despite their higher perceived mobility, may still be highly susceptible to the detriments of habitat fragmentation (Ripperger, Tschapka, Kalko, Rodriguez-Herrera, & Mayer, 2013). It may be advisable, however, to not draw sweeping and definitive conclusions from all such studies.

## Conclusion

The effects of forest fragmentation and habitat destruction can be significant when it comes to bat populations, particularly in the neotropics. The largest driving forces behind habitat destruction are driven by human activity, and their effects are far-reaching, from the micro to macro level, and often occur in a variety of ways. Although some bat species are able to adapt somewhat and utilize what is left when fragmentation occurs, most bat species appear to experience negative trends in abundance, diversity, and overall health. Even though some researchers may have initially believed that the mobility of bats provided them with some measure of insulation against the negative effects of fragmentation, in most studies found this appears to be untrue. The myriad of ways in which habitat destruction negatively affects neotropical bats are only just beginning to be uncovered. Some topics have been broached by researchers mentioned in this paper, such as parasite incidence, mortality rates, genetic connectivity, population diversity, and ramifications such as effects on corresponding plant populations.

It is clear that anthropogenic developments will continue to affect wildlife and that bats in particular are at risk for negative effects. Conservationists need to continue to raise awareness on these topics, as well as come up with more ways to mitigate some of the negative outcomes through further studies of species found in different areas of fragmentation and urban development. With more in-depth knowledge, some possible solutions can be tailored to different areas and populations, whether it include changes in underpasses, as mentioned in the study by Abbott, Harrison, and Butler (2012), increased building of wildlife corridors and forest “islands”, changes that might reduce some of the influence of light and noise pollution, or other even more innovative techniques with the further development of technology and education of those who interact with and learn to value the importance of bats and other wildlife.

## References

Abbott, I. M., Harrison, S., & Butler, F. (2012). Clutter-adaptation of bat species predicts their use under-motorway passageways of contrasting sizes – natural experiment. *Journal of Zoology, 287*: 124-132. DOI: 10.1111/j.1469-7998.2011.00894.x

Avila-Gomez, E. S., Moreno, C. E., Garcia-Morales, R., Zuria, I., Sanchez-Rojas, G., Briones-Salas, M. (2015). Deforestation thresholds for phyllostomid bat populations in tropical landscapes in the Huasteca region, Mexico. *Tropical Conservation Science, 8*(3): 646-661. DOI: 10.1177/194008291500800305

Braaker, S., Kormann, U., Bontadina, F., & Obrist, M. K. (2017). Prediction of genetic connectivity in urban ecosystems by combining detailed movement data, genetic data and multi-path modelling. *Landscape and Urban Planning, 160*: 107-114. DOI: 10.1016/j.landurbplan.2016.12.011

Burns, L., Hutzley, V., & Laubach, Z. (2014). Phyllostomidae: New World leaf-nosed bats. Animal Diversity Web. Retrieved from http://animaldiversity.org/accounts/Phyllostomidae

Cisneros, L. M., Fagan, M. E., & Willig, M. R. (2015). Effects of human-modified landscapes on taxonomic, functional and phylogenetic dimensions of bat biodiversity. *Diversity and Distributions, 21*: 523-533. DOI: 10.1111/ddi.12277

Cleary, K. A., Waits, L. P., & Finegan, B. (2016). Agricultural intensification alters bat assemblage composition and abundance in a dynamic Neotropical landscape. *BIOTROPICA 48*(5): 667-676. DOI: 10-1111/btp.12327

Cosson, J. F., Pons, J. M., & Masson, D. (1999). Effects of forest fragmentation on frugivorous and nectarivorous bats in French Guiana. *Journal of Tropical Ecology, 15*: 515-534/

Cottontail, V. M., Wellinghausen, N., & Kalko, E. K. V. (2009). Habitat fragmentation and haemoparasites in the common fruit bat, *Artibeus jamaicensis* (Phyllostomidae) in a tropical lowland forest in Panama. *Parasitology, 136*: 1133-1145. DOI: 10.1017/S0031182009990485

Cunto, G. C. & Bernard, E. (2012). Neotropical bats as indicators of environmental disturbance: what is the emerging message? *Acta Chiropterologica, 14*(1): 143-151. DOI: 10.3161/150811012X654358

Estrada-Villegas, S., Meyer, C. F. J., & Kalko, E. K. V. (2010). Effects of tropical forest fragmentation on aerial insectivorous bats in a land-bridge island system. *Biological Conservation, 143*: 597-608. DOI: 10.1016/j.biocon.2009.11.009

Ethier, K. & Fahrig, L. (2011). Positive effects of forest fragmentation, independent of forest amount, on bat abundance in eastern Ontario, Canada. *Landscape Ecology, 26*: 865-876. DOI: 10.1007/s10980-011-9614-2

Fensome, A. G. & Mathews, F. (2016). Roads and bats: a meta-analysis and review of the evidence on vehicle collisions and barrier effects. *Mammal Review 46*: 311-323. DOI: 10.1111/mam.12072

Frank, H. K., Mendenall, C. D., Judson, S. D., Daily, G. C., & Hadly, E. A. (2016). Anthropogenic impacts on Costa Rican bat parasitism are sex specific. *Ecology and Evolution 6*(14): 4898-4909. DOI: 10.1002/ece3.2245

Frey-Ehrenbold, A., Bontadina, F., Arlettaz, R., & Obrist, M. K. (2013). Landscape connectivity, habitat structure and activity of bat guilds in farmland-dominated matrices. *Journal of Applied Ecology, 50*: 252-261. DOI: 10.1111/1365-2664.12034

Garcia-Garcia, J. L., Santos-Moreno, A., & Kraker-Castaneda, C. (2014). Ecological traits of phyllostomid bats associated with sensitivity to tropical forest fragmentation in Los Chimpalapas, Mexico. *Tropical Conservation Science, 7*(3): 457-474. DOI: 10.1177/194008291400700307

Giraldo, D. P., Betancur, M. J., & Arango, S. (2008). Food security in development countries: a systemic perspective. *Technology*, *1*, 15. Retrieved from http://s3.amazonaws.com/academia.edu.documents/44083536/GIRAL266.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1498414360&Signature=qUDNHOnEorZhqKp%2FCYB9VaiXzes%3D&response-content-disposition=inline%3B%20filename%3DFood_Security_in_Development_Countries_A.pdf

Golnow, F. & Lakes, T. (2014). Policy change, land use, and agriculture: The case of soy production and cattle ranching in Brazil, 2001-2012. *Applied Geography, 55*: 203-211. DOI: 10.1016/j.apgeog.2014.09.003

Gorresen, P. M. & Willig, M. R. (2004). Landscape responses of bats to habitat fragmentation in Atlantic forest of Paraguay. *Journal of Mammalogy, 85*(4): 688-697.

Heer, K., Helbig-Bonitz, M., Fernandes, R. G., Mello, M. A. R., Kalko, E. K. V. (2015). Effects of land use on bat diversity in a complex plantation-forest landscape in northeastern Brazil. *Journal of Mammalogy, 96*(4): 720-731. DOI: 10.1093/jmmammal/gyv068

Henry, M., Cosson, J., & Pons, J. (2007**a**). Abundance may be a misleading indicator of fragmentation-sensitivity: The case of fig-eating bats. *Biological Conservation, 139*: 462-468. DOI: 10.1016/j.biocon.2007.06.024

Henry, M., Pons, J., & Cosson, J. (2007**b**). Foraging behavior of a frugivorous bat helps bridge landscape connectivity and ecological processes in a fragmented rainforest. *Journal of Animal Ecology, 76*: 801-813. DOI: 10.1111/j.1365-2656.2007.01258.x

Lintott, P. R., Bunnefeld, N., & Park, K. J. (2015). Opportunities for improving the foraging potential of urban waterways for bats. *Biological Conservation, 191*: 224-233. DOI: 10.1016.j.biocon.2015.06.036

Lotze, H. K. (2004). Repetitive history of resource depletion and mismanagement. *Marine Ecology Progress Series*, *274*, 282-285. Retrieved from http://www.jstor.org/stable/24867655

Martins, A. C. M., Willig, M. R., Presley, S. J., & Marinho-filho, J. (2017). Effects of forest height and vertical complexity on abundance and biodiversity of bats in Amazonia. *Forest Ecology and Management, 391*: 427-435. DOI: 10.1016/j.foreco.2017.02.039

McCulloch, E. S., Tello, J. S., Whitehead, A., Rolon-Mendoza, C. M. J., Maldonado-Rodriguez, M. C. D., & Stevens, R. D. (2013). Fragmentation of Atlantic forest has not affected gene flow of a widespread seed-dispersing bat. *Molecular Ecology, 22*: 4619-4633. DOI: 10.1111/mec.12418

Mendes, E. S., Fonseca, C., Marques, S. F., Maia, D., & Pereira, M. J. R. (2017). Bat richness and activity in heterogeneous landscapes: guild-specific and scale-dependent? *Landscape Ecology, 32*: 295-311. DOI: 10.1007/s10980-016-0444-0

Meyer, C. F. J., Struebig, M. J., & Willig, M. R.. (2016). Responses of tropical bats to habitat fragmentation, logging, and deforestation. In C. C. Voigt & T. Kingston (Eds.) *Bats in the Anthropocene: Conservation of Bats in a Changing World*, pp. 63-103. DOI: 10.1007/978-3-319-25220-9_4

Morton, D. C., DeFries, R. S., Shimabukuro, Y. E., Anderson, L. O., Arai, E., del Bon Espirito-Santo, F., Freitas, R. & Morisette, J. (2006). Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proceedings of the National Academy of Sciences of the United States of America, 103*(39):14637-14641. DOI: 10.1073/pnas.0606377103

Nature Conservancy. (n.d.). Spooky science: Bat trivia. Retrieved from https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arizona/top-10-bat-facts.xml

Quesada, M., Stoner, K. E., Rosas-Guerrero, V., Palacios-Guevara, C., & Lobo, J. A. (2003). Effects of habitat disruption on the activity of nectarivorous bats (*Chiropera: Phyllostomidae*) in a dry tropical forest: implications for the reproductive success of the neotropical tree *Ceiba grandiflora*. *Oecologia, 135*: 400-406. DOI: 10.1007/s00442-003-1234-3

Quesada, M., Stoner, K. E., Lobo, J. A., Herrerias-Diego, Y., Palacios-Guevara, C., Munguia-Roses, M. A. . . . Rosas-Guerrero, V. (2004). Effects of forest fragmentation on pollinator activity and consequences for plant reproductive success and mating patterns in bat-pollinated bombacaceous trees. *Biotropica, 36*(2): 131-138.

Ripperger, S. P., Tschapka, M., Kalko, E. K. V., Rodriguez-Herrera, B., & Mayer, F. (2013). Life in a mosaic landscape: anthropogenic habitat fragmentation affects genetic population structure in a frugivorous bat species. *Conservation Genetics, 14*: 925-934. DOI: 10.1007/s10592-012-0434-y

Ripperger, S. P., Tschapka, M., Kalko, E. K. V., Rodriguez-Herrera, B., & Mayer, F. (2014). Resisting habitat fragmentation: High genetic connectivity among populations of the frugivorous bat *Carollia castanea* in an agricultural landscape. *Agriculture, Ecosystems, and Environment, 185*: 9-15. DOI: 10.1016/j.agee.2013.12.006

Rocha, R., López-Baucells, A., Farneda, F. Z., Groenenberg, M., Bobrowiec, P. E. D., Cabeza, M., . . . Meyer, C. F. J. (2017). Consequences of a large-scale fragmentation experiment for Neotropical bats: disentangling the relative importance of local and landscape-scale effects. Landscape Ecology, 32(1): 31-45. DOI:10.1007/S10980-016-0425-3

Rodrigues-San Pedro, A., & Simonetti, J. (2015). The relative influence of forest loss and fragmentation on insectivorous bats: does the type of matrix matter? *Landscape Ecologyu, 30*(8): 1561-1572. DOI: 10.1007/s10980-015-0213-5

Russo, D. & Ancillotto, L. (2015). Sensitivity of bats to urbanization: a review. *Mammalian Biology, 80*: 2015-212. DOI: 10.1016/j.mambio.2014.10.003

Stoner, K. Quesada, M., Rosas-Guerrero, V., & Lobo, J. (2002). Effects of forest fragmentation on the Colima long-nosed bat (*Musonycteris harrisoni*) foraging in tropical dry forest of Jalisco, Mexico. *BIOTROPICA, 34*(3): 462-467.

Wang, L. F., Walker, P. J., & Poon, L. L. (2011). Mass extinctions, biodiversity and mitochondrial function: are bats ‘special’as reservoirs for emerging viruses?. *Current opinion in virology*, *1*(6), 649-657.